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Measurement of Radon-222 concentration levels in water samples in Sudan

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ABSTRACT

In the present research, the number of water samples is 248, collected from various places and locations in the Sudan. Then radon concentration values have been measured using passive integrated solid-state nuclear track devices containing allyl diglycol carbonate plastic detectors. Results show that the minimum average value of radon concentration found in the main channel water samples to be (6.93±1.68)Bq/L, while the maximum average value measured in Sagia (2) water samples to be (22.74±4.89) Bq/L. From our study, we found that there are no any remarkable variations seen in radon concentration for water samples taken from Hafeirs and Rivers. The overall average radon concentration for all water samples is found to be (14.24 ± 3.62) Bq/L. These values are lower than the maximum allowable concentration in water as recommended by US Environmental Protection Agency EPA.

Key words: Allyl diglycol carbonate plastic detectors, radon-222 concentration levels, irrigation channel.

INTRODUCTION

Radon (^{222}Rn) is a naturally occurring radioactive gas with a half-life of 3.82 days that is part of the uranium decay series. The contribution to the mean effective dose equivalent from inhalation of ^{222}Rn and its short-lived decay products (^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po) estimated to be about 50% of the total effective dose equivalent from natural radiation sources [1]. The presence of ^{222}Rn in the environment and ground waters is associated mainly with trace amounts of uranium and its immediate parent, radium-226, in rocks and soil. Radon can easily lose from water when it is agitated for example, when river or other water sources flows over rocks or moved by wind [2].

Radon can also transported with water to indoors, during water usage as dishwashing, cooking, boiling, spraying, laundering and taking shower, which, in consequence, leads to an increase of its concentration in bathrooms and kitchens [3, 4, and 5]. The concentration in indoor air also depends on the building's volume and its ventilation. Radon concentration changes markedly from low in fresh superficial water to relatively high in drilled well water [6, 7]. Direct inhalation is probably the most likely mechanism that radon enters into our body, although other route such as dermal sorption is possible [8]. Health an implication of radon in drinking water (The source of drinking water such as well water, river water, Hafier and irrigation channel waters considering an important factor for limiting radon levels in drinking water) refers to ingestion of dissolved radon will result in a radiation dose to the lining of the stomach. Moreover, inhalation of radon gas that released from water sources will contribute to the radon content of indoor air and, if inhaled, will result in a radiation dose to the lung [3, 4, 8-12]. Long-term exposure to high concentrations of radon in indoor air increases the risk of lung cancer [11]. To monitor radon, both active and passive techniques developed in various countries all over the world [13-21]. Active methods used for short-term measurements of radon. Passive methods are more suitable for the assessment of radon exposure over long time scales and for large-scale surveys at moderate cost. Solid-state nuclear track detectors (SSNTDs) have low costs and more convenient for long-term measurements of radon and its progeny in the environment [2].

The aim of this study is the measurement of radon contained in water samples in the Sudan. We also aims to determine the distribution of radon activity concentrations in water samples in order to build database information for future researches in evaluating radon concentration levels in the Sudan. Limited investigations carried out in selected regions to study radon concentration in soil and indoor air in some parts of Sudan [22-25]. In this study, effort has been taken to estimate radon released from (248) water samples in various locations in the Sudan.

MATERIALS AND METHODS

In this work, a verity of water samples collected from different locations in the Sudan (eleven locations, in a number of 248 measurements). The sampling sites include well water (Swagi waters used for irrigation and sometimes as drinking water), Totiel water, White Nile sample, Gash river water, Nahr Atbara water, Hafeir water, Kalhout irrigation channel, main channel water and Halfa Aljadida irrigation channel water. The samples analyzed by using closed can technique [26]. The water samples collected from the depth of about 30ft to 150ft from ground level. Shallow levels chosen to be below 50ft while deep water level chosen from about 50ft to 150ft. After collection, the samples taken into a bottle of 10cm in diameter and 35cm in height and were filled with 900 gems of water. Then detectors were hung from the bottom of the cap inside the bottle and made airtight and were exposed to radon for 90 days. The 'CR-39' plastic sheets was preserved within a paper properly covered so that it was not exposed to outside air or any other sources which may emit alpha particles. However, it may somehow expose to alpha particles, before its actual used for exposure. Ten detectors were prepared for calibration process and three for the background. After exposing, the detectors separated from the sample cup, collected and chemically etched in a 30% solution of KOH, at $(70.0 \pm 0.10)^{\circ}\mathrm{C}$ for a period of 9 hours. The resulting α tracks counted manually under an optical microscope of magnification 400X. The track density was determined and converted into activity concentration C ($Bq.m^{-3}$) by using the following formula [27]:

$$C = \frac{\rho}{K\,t} \tag{1}$$

Where ρ is the track density (tracks per cm^2), K is the calibration constant ($K=3.2307\times10^{-3}$ $tracks.cm^{-2}.h^{-1}/Bq.m^{-3}$) C is the radon concentration in $Bq.m^{-3}$, and t is the exposure time.

The calculations of radon activity density in water C_W were done by using the formula [27].

$$C_W = \frac{\lambda C h t}{L} \tag{2}$$

Where λ is the decay constant of radon-222, h is the distance from the surface of water in the sample cup to the detector, t is the exposure time of the sample and L is the depth of the sample.

RESULTS AND DISCUSSION

In this survey, a total number of 248 water samples were collected and analyzed to measure the radon concentrations released from various water samples in the Sudan. Tables 1 and 2, Figs. 1-3 show the results of radon concentration in water samples.

Table 1, Figs. 1, and 2 show the results of radon concentration and the values of pH and T.D.S for the samples in the study.

The minimum value of radon concentration of water samples and the minimum average value from the selected location in the Sudan were found to be 3.05 Bq/L and (6.93 ± 1.68)Bq/L, in the main channel water near Khashm Algirba town, while the pH and T.D.S values were found to be 6.89 and 195mg/L respectively.

The highest individual value and the maximum average value of radon concentration form all of water samples were recorded in Sagia (2) a type of well water to be 57.46 Bq/L and (22.74±4.89)Bq/L, respectively with pH value of 7.26 and T.D.S. value of 398mg/L.

The overall average value from all water samples from the selected locations in the Sudan is (14.24 ± 3.62) Bq/L, with pH value of 7.40 and T.D.S. value of 284.45 mg/L.

The main channel near Khashm Algirba town recorded the minimum value of concentration. From our results, both main channel and Halfa irrigation channel recorded values of (7.82±2.16 Bq/L, pH of 7.30 and T.D.S. of 210 mg/L) respectively. We can mention that they originated from Atbara River. While Kalhout irrigation channel (9.83±3.41

Bq/L, pH of 6.99 and T.D.S. of 265 mg/L), was supplied from Algash River. The low concentrations of irrigation channels are consistent with the idea that the radon concentration decreases with a higher water velocity [28].

For the radon concentration values of Hafeir water (12.70±3.31 Bq/L, pH of 6.87 and T.D.S. of 275 mg/L), we can mention that water in Hafeir is stagnant and thus the probability of radon aeration is larger [29].

The highest individual value of radon concentration in Sagia(2) may be due to the source of water as it is a private well situated in a porous sedimentary basement aquifer near Al-Gash River. Higher porosity might allow the radon gas to escape easily while the lower porosity of the soil and intact rocks above the aquifer reduces the probability of gas escape [29]. Groundwater movement, water table depth, and its ability to leach radioactive materials from underlying bedrock during this movement is considered one of the important factors in the variation of radon concentration in water [30]. Sagia (1) (21.02±4.84 Bq/L, pH of 8.50 and T.D.S. of 350 mg/L), dug well (18.22±4.72 Bq/L, pH of 7.66 and T.D.S. of 254 mg/L) and Toteil waters (17.06±3.62 Bq/L, pH of 7.00 and T.D.S. of 287 mg/L) are well waters. Sagia (1) and dug well are shallow dug wells essentially used for both plant irrigation and as drinking water, we notice that the water from these sources(public sources) are not subjected to any treatment or filtration before pumping, thus its composition is observed to be mixed with visible particles. This may enhance the amount of probability of its ability to carry a sizable load radioactive material. Toteil well is a type of open dug well with low depth from three to seven meters, situated on the hard rock's of Kassala Mountain. It used to save the rainwater, which collected continuously by a pipe network from the top of the Mountain. We may recall several hydro-geological reasons that might cause variations in water radon concentration from place to another. Hess et. al, has shown that well water has higher concentration of radon than the water from the public utility systems [31]. Seidel *et al.* reported that, higher radon concentrations in wells correlated with low transmissivity or low permeability and inversely [28]. The degree of aeration would be the first reason, where gases like radon will escape from collected rainfall water as of Toteil much easier more than for dug wells such as Sagia. The deeper wells hold most of the radon, while open water is closer to the earth surface allows gases to escape easily [29]. In Finland, the mean concentration of radon in drilled wells found to be 460 Bq/L, and in wells dug in the soil is 50 Bq/L [32].

For water samples taken from Algash River (19.22±4.97 Bq/L, pH of 7.90 and T.D.S. of 309 mg/L), Atbara River water (12.97±3.12 Bq/L, pH of 8.01 and T.D.S. of 310 mg/L) and White Nile water (10.26±3.01 Bq/L, pH of 6.98 and T.D.S. of 276 mg/L).

It is apparently clear that there is no remarkable variation in radon concentration in Hafier and River waters, although rivers carried the clay and soils and various types of elements [33]. This should increase the probability of containing a large amount of radium element to appear in increasing the radon concentration in the samples. In our survey the water samples has a pH ranging from 6.87 to 8.5.

The total concentration of dissolved material is determined from the weight of the dry residue after the evaporation of the water sample at 180°C. This solid residue does not completely coincide with the dissolved material, which was originally in the solution since dissolved gases are lost and bicarbonate converted to carbonate with the loss of CO_2.

Table 1 Radon concentration, *pH* and *T.D.S.* values in different water samples from various locations in Sudan

No.	Location	No.	Min C. (Bq/L)	Max. C (Bq/L)	(mean± s.d) Bq/L	pH	T.D.S. (mg/L)
1	Dug Well Water	22	8.41	49.65	18.22±4.72	7.66	254
2	Sagia- 1(Well water)	23	9.78	37.9	21.02±4.84	8.5	350
3	Sagia-2 (Well water)	22	6.43	57.46	22.74±4.89	7.26	398
4	Totiel (Well water)	22	7.1	32.41	17.06±3.62	7.00	287
5	White Nile Water	24	6.55	17.33	10.26±3.01	6.98	276
6	Gash River Water	21	9.64	39.82	19.22±4.97	7.90	309
7	Atbara River Water	24	5.82	20.64	12.97±3.12	8.01	310
8	Hafeir Water	23	5.89	24.64	12.70±3.31	6.87	275
9	Kalhout Irrigation Channel –Kassala	22	5.63	15.67	9.83±3.41	6.99	265
10	Halfa Irrigation Channel	24	3.76	12.78	7.82±2.16	7.30	210
11	Main Channel Water (Khashm Algirba)	21	3.05	11.35	6.93±1.68	6.89	195
		248	3.05	57.46	14.24 ± 3.62	7.40	284.45

In our study, the total dissolved solids reported range from 195 to 398 mg/L. The distribution of the total solids does not follow any pattern in the samples**.**

In some countries such as in Maine (U.S), the T.D.S values are slightly greater in water samples containing high-unsupported levels of radon [34]. Such water might contribute to indoor radon levels [1]. An important source of indoor radon is radon rich- water. In fact, it estimated that approximately 10^4 Bq/L in water would result in 1Bq/L in air. The ratio of radon concentration in air to that in water, however, depends on water use and room ventilation [35, 36].

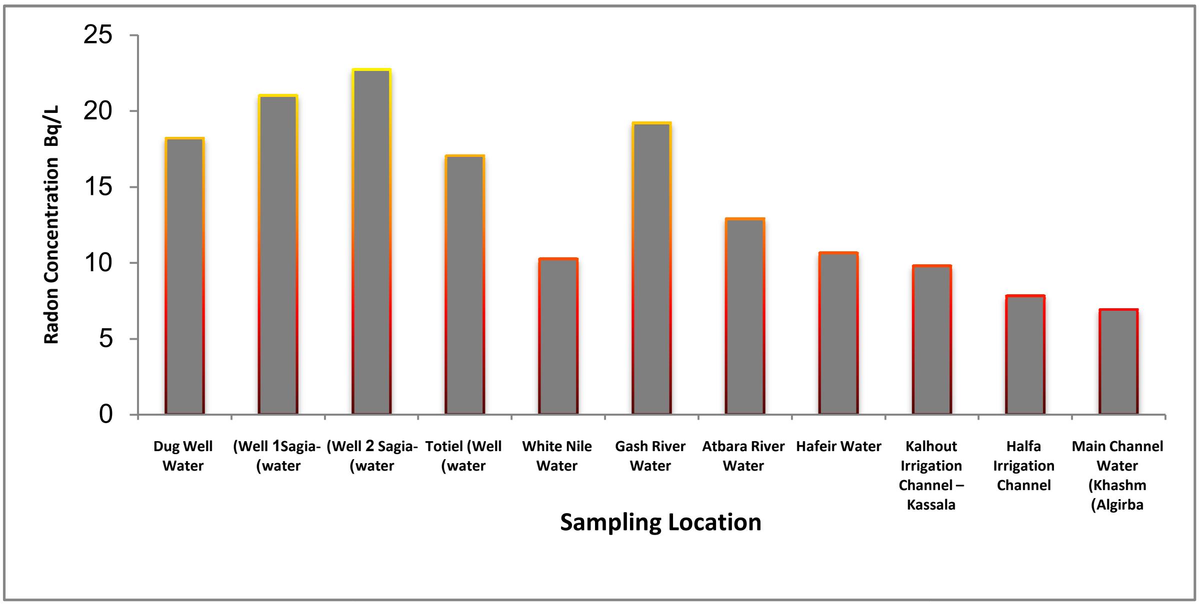

Fig.1 Radon concentration from different water samples from different locations in the Sudan

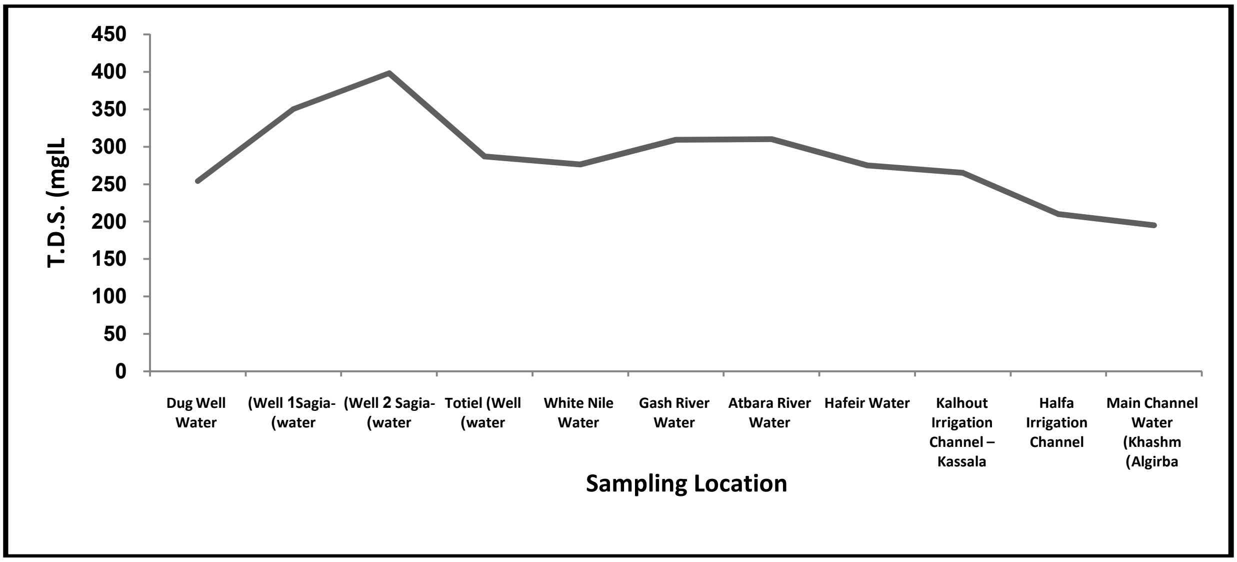

Fig. 2 The relation between T.D.S. and the sampling location in the Sudan

Table 2 and Fig. 3 summarize the radon concentration for well water, river water and Hafier and Irrigation channel water samples in the Sudan. These results reflect that the radon concentration in well water is higher (19.76±4.54 Bq/L), with pH and T.D.S. values of 7.61 and 322.25 mg/L. For river water, the average value of radon concentration found to be 14.13±3.70 Bq/L, with pH and T.D.S. of 7.63 and 298.33 mg/L. and 8.80±2.64 Bq/L for Hafier and Irrigation channel water samples with pH and T.D.S of 7.01 and 236.25 mg/L. The descending order ordering of Radon concentration in water samples can be arranged and order as follows: well water> river water > Hafier and Irrigation channel water.

Table 2 Radon concentration, *pH* and *T.D.S.* value for well water, river water and Hafier and irrigation channel waters in Sudan

No.	Location	No.	Min C. (Bq/L)	Max. C (Bq/L)	(mean± s.d) Bq/L	pH	T.D.S. (mg/L)
1	Well Water	89	6.43	57.46	19.76 ± 4.54	7.61	322.25
2	River Water	69	5.82	39.82	14.13 ± 3.70	7.63	265.33
3	Hafier and Irrigation Channel Water	90	3.05	24.64	8.80 ± 2.64	7.01	261.00

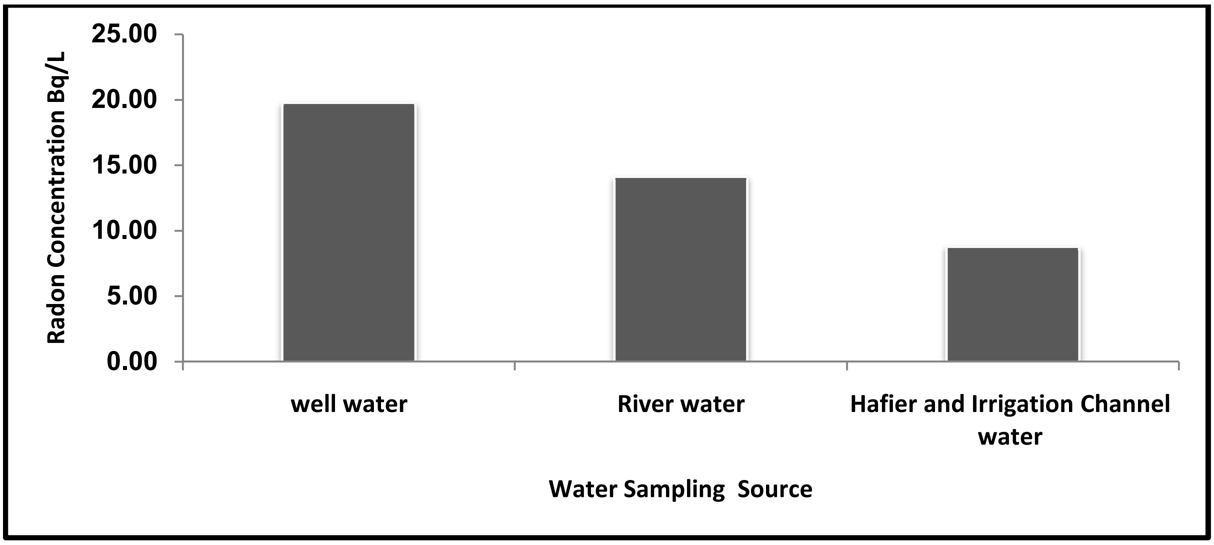

Fig.3 Radon concentration in well water, river water and Hafier and irrigation channels water in the Sudan

The radon concentration measured in all water samples in the Sudan is lower than the maximum allowable concentration in portable water 18 Bq/L, as recommended by EPA [37]. In the UNSCEAR, 1982 Report (Annex D, Paragraph 163) it was tentatively estimated that between 1% and 10% of the world's population consumes water-containing concentration in order of 100 Bq/L or higher, drawn from relatively deep wells [38]. For remainder, who consume water from aquifers or surface sources, the weighted world average concentration is probably less than 1 Bq/L [38]. This is under the maximum allowable radon concentration from water as recommended by EPA and UNSCEAR for the weighted world average concentration of waters drawn from relatively deep wells, but higher than the weighted world average concentration of water from aquifers or surface sources [37, 38]. It is apparent that radon in water is a significant source of radon in dwellings only when the radon concentration in water is the order of 10 Bq/L or more [39], or above 400 Bq/L as recommended by UNSCEAR [40].

CONCLUSION

In this study, measurements of radon concentration in well, river, Hafier, and irrigation channel water samples from various locations in the Sudan. On the average, radon concentration was 19.76±4.54 Bq/L for well waters, 14.13±3.70 Bq/L for river waters, and 8.80±2.64 Bq/L for Hafier and irrigation channel waters.

The overall average radon concentration for all water samples found to be (14.24±3.62)Bq/L, which is under the maximum allowable radon concentration in water as recommended by EPA. The average contribution of radon concentration in water to indoor radon concentration was (14.24±3.62) $\times 10^{-4}$ Bq/l. from our survey we may conclude that there are no any remarkable variations seen in radon concentration for water samples taken from Hafier and Rivers, while irrigation channels relatively showed the minimum concentration. From this survey, the pH and T.D.S. average values are 7.4 and (2.84 mg/L), respectively.

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