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Research Article

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Determination of Radon-222 Levels and Hazards in Air Samples, Quarriers Cement Factories in River Nile State, Sudan

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Abstract The most portion of the contributed background radiation dose is due to natural radionuclides such as ^{226}Ra and ^{222}Rn. Radon (^{222}Rn) a member of ^{238}U decay chain, having no odorcolorless, weightier than air and is the daughter of radionuclide of ^{226}Ra. It is a natural radioactive noble gas with a half-life of 3.82 days which can enter the human body through drinking water or by inhalation [1]. The alpha ray emitted from ^{222}Rn and it's daughters (^{218}Po and ^{214}Po) in the long term can damage the DNA of lung cells and cause lung cancer [2]. During the day all humans are exposed to ^{222}Rn in the air atmosphere [3], so The World Health Organization [4] has approved the direct relation between lung cancer increasing and the concentration of ^{222}Rn in the indoor air [5].

EPA has announced deaths from indoor air of ^{222}Rn approximately 21,000 people a year, which is 10 times as many deaths from air pollution [4,6]. WHO and EPA have been proposed guidelines and standard limits are equal to 148 Bq/m^3 and 100 Bq/m^3, for ^{222}Rn in indoor air, respectively [6]. The global mean of ^{222}Rn concentration in the air of both sites indoor and outdoor is 48 Bq/m^3 and 15 Bq/m^3, respectively [7]. UNSCEAR stated that the effective dose from natural radiation 2.5 mSv/y that 1 mSv/y is due to ^{222}Rn in the air [8]. Committee on Radiation Protection (ICRP) expressed the maximum effective dose from inhalation of ^{222}Rn for ordinary people 1 mSv/y [9]. More than 50 percent of the annual effective dose by individuals due to ^{222}Rn is (1.3 mSv /y) [10].

Keywords Radon concentration, Indoor air, Effective dose, Lung cancer risk

Introduction

The most portion of the contributed background radiation dose is due to natural radionuclides such as ^{226}Ra and ^{222}Rn. Radon (^{222}Rn) a member of ^{238}U decay chain, having no odorcolorless, weightier than air and is the daughter of radionuclide of ^{226}Ra. It is a natural radioactive noble gas with a half-life of 3.82 days which can enter the human body through drinking water or by inhalation [1]. The alpha ray emitted from ^{222}Rn and it's daughters (^{218}Po and ^{214}Po) in the long term can damage the DNA of lung cells and cause lung cancer [2]. During the day all humans are exposed to ^{222}Rn in the air atmosphere [3], so The World Health Organization [4] has approved the direct relation between lung cancer increasing and the concentration of ^{222}Rn in the indoor air [5].

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Materials and Methods

Area of study

River Nile State locate in Northern Sudan with a population of over 1.4 million. The study area of study located at a distance of 310 km from Khartoum city the capital of Sudan. River Nile State is rich in raw materials that can be used for cement industry, so many cement factories have been established there. The area locates at the geographic coordinates 33°77'88" E and 17° 70'6" N (Figure 1) [11].

^{222}Rn concentration measurement

First, a reference measurement area was selected and the radon gas volume ^{222}Rn was measured in a number of quarries equipped to take cement ore. ^{222}Rn air concentration was measured using portable device Radon Scout Plus meters device GmbH which made by SARAD company in Germany (Figure 2).

The sensitivity of this device is 1.8 counts/ min× KBq/m^3 (independent on the humidity) and response time 120 minutes to 95% of the final value [12]. High sensitivity with alpha spectrometry analysis, leads to a short response time even at low concentrations. According to the measuring instructions provided by SARAD company, for continuousmeasurement; more than 3hours; the device should be placed in slow mode to increase the accuracy[13], Measurement of ^{222}Rn concentration was done in five quarries of cement.

Due to the measurement of ^{222}Rn concentration in indoor air guidelines, measuring was designed for 24 consecutive hours of each quarry (recommended by the EPA). After completion of the measurement of ^{222}Rn concentration in indoor air, and outdoor air sites, also the concentration of ^{222}Rn was carried out for 3 hours (background) near the entrance of quarries. In sum, the 50 measurements of ^{222}Rn were done in indoor air of quarries.

Calculation effective dose and risk of lung cancer

Estimation of annual effective dose by the indoor air ^{222}Rn (E_{Rn}) was conducted by UNSCEAR equation;

$$E_{Rn}\ (mSv / y) = C_{Rn} \times 0.4 \times 7000 \times 9 \times 10^{-6} \quad (1)$$

In this equation, geometric mean concentrations of indoor air ^{222}Rn (Bq/m^3), 0.4 is equilibrium factor of decay products of ^{222}Rn, 7000 (h/y) is equal to 80% of the year (the settlement) and 9 is (nSv/Bq.m^3.h) feed conversion ratio of ^{222}Rn concentration to annual effective dose and 10-6 conversion ratio of nano Sv/mSv [14].

To calculate the probability of lung cancer cases per million people (CPPP) by effective dose from ^{222}Rn, equation (2) was used [15].

$$CPPP = E_{Rn} \times 18 \times 10^{-6}\ mSv^{-1}.y \quad (2)$$

Results and Discussion

The mean and the annual range of ^{222}Rn concentration in indoor air of all cement quarries are (25.64 ±4.4) Bq/m^3. The range concentrations of background air of ^{222}Rn are (12±2) Bq/m^3. The highest and lowest concentrations of ^{222}Rn in the indoor air of all cement quarries are No.35 (9± 1.5 Bq/m^3) and No. 49 (188 ± 31) Bq/ m^3, respectively (Table 1).

The mean concentration of ^{222}Rn indoor air relative to WHO and EPA standards are 25.6% and 38.5 %, respectively (Figure1). Like the River Nile State area, the concentration of ^{222}Rn indoor air of all cement quarries is less than the WHO guideline and EPA standard limits.

The annual mean effective dose of ^{222}Rn in all cement quarries River Nile State are (0.66 ±0.11) mS/y. Effective dose by residents of River Nile State is less than standard ICRP (1mSv/y) [16,17].

Table 1: ^{222}Rn concentrations (Mean±SD) Bq/m^{3}of indoor air samples of quarries cement factories River Nile State, Sudan

No	^{222}Rn concentration (Bq/m^3)	Effective dose (mSv/y)	Lung cancer risk	No	^{222}Rn concentration (Bq/m^3)	Effective dose (mSv/y)	Lung cancer risk
1	28 ±4.8	0.70 ± 0.12	12.6 ±2.2	26	35 ±5.9	0.88 ±0.15	15.8 ±2.7
2	20 ±3.4	0.50 ±0.08	9 ±1.4	27	59 ±1.0	1.49 ±0.25	26.8 ±4.5
3	15 ±2.6	0.38 ±0.06	6.8 ±1.1	28	18 ±3.0	0.45 ±0.07	8.1 ±1.3
4	23 ±3.9	0.58 ±0.10	10.4 ±1.8	29	37 ±6.3	0.93 ±0.16	16.7 ±2.9
5	18 ±3.0	0.45 ±0.07	8.1 ±1.3	30	21 ±3.6	0.53 ±0.09	9.5 ±1.6
6	21 ±3.6	0.53 ±0.09	9.5 ±1.6	31	26 ±4.4	0.66 ±0.12	11.9 ±2.2
7	24 ±4.0	0.60 ±0.10	10.8 ±1.8	32	21 ±3.6	0.53 ±0.09	9.5 ±1.6
8	15 ±2.6	0.38 ±0.06	6.8 ±1.1	33	26 ±4.4	0.66 ±0.12	11.9 ±2.2
9	20 ±3.4	0.50 ±0.08	9 ±1.4	34	23 ±3.9	0.58 ±0.10	10.4 ±1.8
10	12 ±2.0	0.30 ±0.05	5.4 ±0.9	35	9 ±1.53	0.23 ±0.04	4.14 ±0.72
11	12 ±2.0	0.30 ±0.05	5.4 ±0.9	36	20 ±3.4	0.50 ±0.08	9 ±1.4
12	21 ±3.6	0.53 ±0.09	9.5 ±1.6	37	29 ±4.9	0.73 ±0.11	13. ±2.0
13	28 ±4.7	0.70 ±0.12	12.6 ±2.2	38	20 ±3.4	0.50 ±0.08	9 ±1.4
14	36 ±6.1	0.91 ±0.15	16.3 ±2.7	39	23 ±3.9	0.58 ±0.10	10. ±1.8
15	29 ±4.9	0.73 ±0.12	13.1 ±2.2	40	15 ±2.6	0.38 ±0.06	6.8 ±1.1
16	38 ±6.5	0.96 ±0.16	17.3 ±2.9	41	18 ±3.0	0.45 ±0.07	8.1 ±1.3
17	18 ±3.0	0.45 ±0.07	8.1 ±1.3	42	26 ±4.4	0.66 ±0.12	11.9 ±2.2
18	15 ±2.6	0.38 ±0.06	6.8 ±1.1	43	38 ±6.5	0.96 ±0.16	17.3 ±2.9
19	32 ±5.4	0.81 ±0.14	14.6 ±2.5	44	15 ±2.6	0.38 ±0.06	6.8 ±1.1
20	32 ±5.4	0.81 ±0.14	14.6 ±2.5	45	12 ±2.0	0.30 ±0.05	5.4 ±0.9
21	20 ±3.4	0.50 ±0.08	9 ±1.4	46	15 ±2.6	0.38 ±0.06	6.8 ±1.1
22	12 ±2.0	0.30 ±0.05	5.4 ±0.9	47	15 ±2.6	0.38 ±0.06	6.8 ±1.1
23	29 ±4.9	0.73 ±0.11	13.1 ±2.0	48	26 ±4.4	0.66 ±0.11	11.9 ±2.2
24	26 ±4.4	0.66 ±0.12	11.9 ±2.2	49	188 ±31.9	4.74 ±0.80	85.32 ±14.4
25	26 ±4.4	0.66 ±0.12	11.9 ±2.2	50	12 ±2.0	0.30 ±0.05	5.4 ±0.9
				Min	**9 ±1.53**	**0.23 ±0.04**	**4.14 ±0.72**
				Max	**188 ±31.9**	**4.74 ±0.80**	**85.32 ±14.4**
				Mean	**25.64 ± 4.4**	**0.66 ±0.11**	**11.7 ± 1.98**

The mean and annual ranges concentration of ^{222}Rn indoor air of quarries cement factories is 25.64 ± 4.4Bq/m^3. Also, the mean and range of annual background air of ^{222}Rn is 12±2 Bq/m^3.The highest and lowest concentrations of ^{222}Rn indoor air of the No.49 are (188 ±31.9Bq/m^3) and 35 (9 ±1.53Bq/m^3) (Table 1).

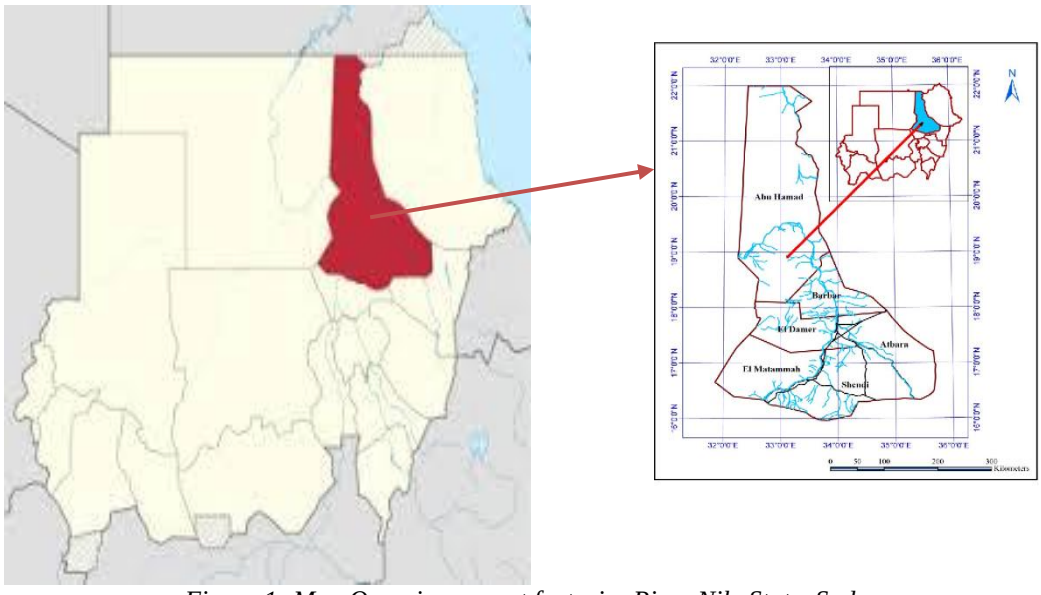

Figure 1: Map Quarries cement factories River Nile State, Sudan

Figure 2: A portable device Radon Scout Plus meters

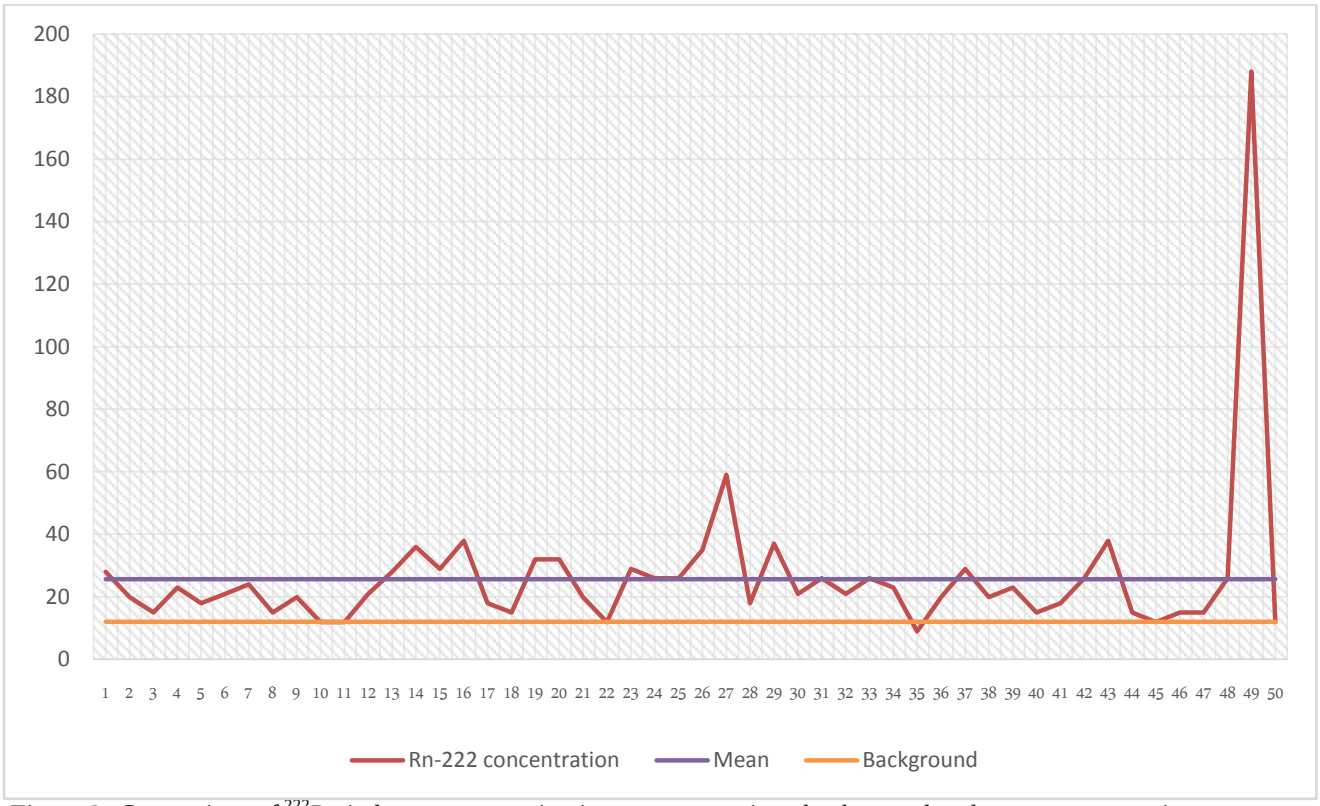

Figure 3: Comparison of ^{222}Rn indoor concentration in cement quarriers, background and mean concentration

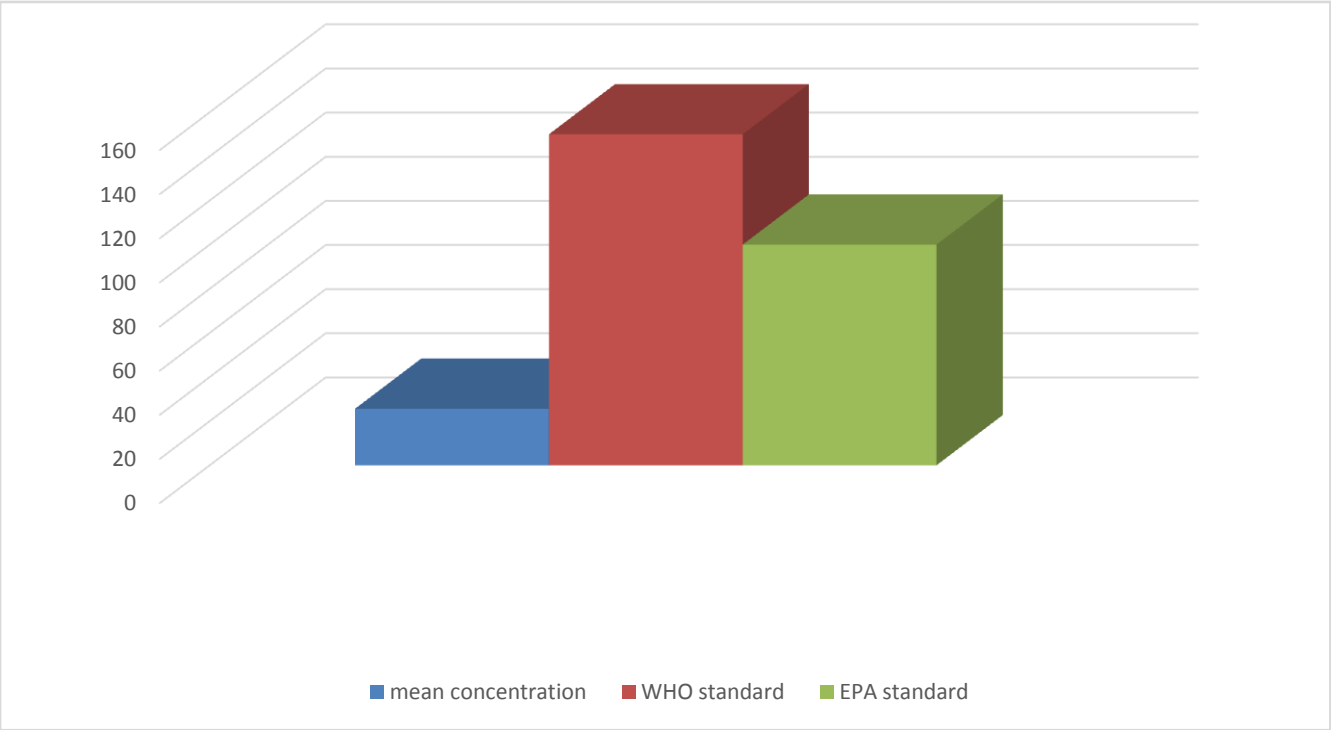

Figure 4: *Comparison between the mean concentration of ^{222}Rn, WHO standard and EPA standards in cement quarriers*

Conclusions

Since the statistical analysis didn't show any significant difference between the background concentrations of ^{222}Rn of all cement quarriers.Based on the UNSCEAR guidelines for annual doses of ionizing radiation by source, the recommended upper threshold effective dose of total radon and their progenies is 1 mSv/y, with a typical range of observed doses up to 0.66 ±0.11mSv/y. The mean risk of lung cancer in the cement quarriers is 11.7 ± 1.98 which is much lower than the standard ICRP (170-230 lung cancer).

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