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Measurements of Radon gas Concentration in a Soil at Some Towns in Kassala State

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ABSTRACT

In this work, radon gas concentration in the soil of some towns in Kassala State in eastern Sudan was measured. To perform this task 206 soil samples were studied randomly. The study was made on: Kassala (90 soil samples), Aroma (40 soil samples), Khashm Algirba (36 soil samples) and Halfa Aljadida city (40 soil samples). Previously calibrated dosimeters containing solid state nuclear track detectors SSNTDs type of CR- 39 were used. The soil- radon gas concentration obtained in Kassala town ranged from 452.10 Bq/m^3 to 7766.89 Bq/m^3, with an average of (2885.98±419.36) Bq/m^3. In Aroma town, soil-radon gas concentration ranged from 1942.99 Bq/m^3 to 5727.38 Bq/m^3, with an average of (3336.89±500.99) Bq/m^3. While in Khashm Algirba town the soil radon gas concentration was found to be in the range between 807.68 Bq/m^3 and 5227.03 Bq/m^3 with an average of (2169.00 ± 436.99) Bq/m^3. In Halfa Aljadida the soil - radon gas concentration values ranged between 1023.56 Bq/m^3 and 4145.05 Bq/m^3, with an average of(2106.08±397.40) Bq/^{m3}. The minimum average of soil- radon gas concentration was found to be in Kassala State where the concentration is (2624.49 ± 438.69) Bq/m^3. It was also found that soil- radon gas concentration increased with depth.

Keywords: Radon; Soil - radon gas concentration; CR-39; kassala State.

INTRODUCTION

Radon is a radioactive noble gas that does not chemically react with other elements. However, it can change the physical properties of the surrounding medium. Its half- life allows it to migrate long enough to travel long distances and accumulate indoors. Radon is the sole alpha- emmiting gas and can be detected with less chance of phenomena altering the measure-ments. Its presence on earth is very limited (4 x 10-7 in weight)(Anderson, 1947), yet it is almost completely ubiquitous. Radon has three isotopes: ^{222}Rn (radon), from ^{238}U chain, with a half- life($\tau_{\frac{1}{2}}$ = 3.82 day); ^{220}Rn or thoron from the ^{232}Th chain, with a short half- life ($\tau_{1/2}$ = 55 s), and ^{219}Rn or actinon from the ^{235}U chain, has also a short half- life ($\tau_{1/2}$ = 4 s). Because of the low activity of ^{235}U (0.07%), action is not significant for human exposure. The same applies to a lesser extent to thoron. According to UNSCEAR, radon conistitutes the major contribution to the dose to which people are exposed (UNSCEAR, 2000). It is the second leading cause of lung cancer, after smoking. It can affect just about anyone, anywhere (Guimond and Page, 1992). The action level of indoor radon concentration is (200- 600) Bq/m3 as recommended by ICRP (ICRP, 1993). A world average concentrations for soils is about 24Bq/kg for both ^{238}U and ^{232} Th (Wilkening, 1985). Radon is produced through the alpha decay of its immediate parent ^{226}Ra within rock grains that contain uranium and its daughters in seqular equilibrium. In general, the health hazards of radon and its daughters result from the inhalation of these radioactive elements (Kunz et. al.,1981). These daughters attach themselves to dust particle present in the air. The attached or unattached daughters of radon may be inhaled and become lodged in the nasal passage, trachea and pulmonary tree or pulmonary parenchyma that causes damage of tissues of the lung (Kobal et. al., 1987; Khan el. Al., 1990). The main source of increased radon indoor concentration is soil (Nero and Nazaroff, 1984; Narayana et. al., 1998). For a given radium concentration in a certain rock speciments, the amount of radon that escapes depends on certain parameters such as: grain size, rock type, permeability, moisture content (Shweikani et al., 1995; Gundersen, 1992), beside thermal history (Monnin and Seidel, 1993). The radon concentration in the ground depends on the radium content of the soil and the emanation power of soils and rocks (Nishimura and Katsura, 1990; Mukhtar and Elzain., It is also governed by the 2006; Salvatore et ale, 1993). mechanisms of migration of radium and by the climate factors such as soil and air temperature (Magro- Campero and Fleischer, 1977), atmospheric pressure (Klusman and Jaacks, 1987), wind- turbulence effects on the air - soil surface, rain fall and the earth tidal effects (Gingrich, 1984; Rose et al., 1979; Hinkle, 1990). Soil – radon gas concentration has been the subject of many studies (Mauzar et al., 1999; Jönsson et al.,1999; Abumurad et al., 1997; Akerblom et al., 1984).

This study was carried out during the the period July- October 2002. The aim of this work is to determine soil- radon gas concentration levels as a major source of indoor radon and studying the effect of depth on the variations of soil- radon gas concentration in the soils of Kassala State towns .

Measurement Technique

Time- integrated passive diffusion radon dosimeters were used for the measurement of soil- radon gas concentration. The passive dosimeters were described in a previous works (Al-Bataina and Elzain, 2003; Abumurad et al., 1997). The study area is the eastern part of Sudan in an area of 42330 lan2 (Figure 1). This area is characterized by two seasons: the hot summer (April — September), with rain fall (during July up to October) and a relatively short winter (from November up to May). The soils are moderately well drained, and slowly permeable .Four towns were chosen namely: Kassala (90 soil dosimeters), Aroma (40 soil dosimeters), Khashm Algirba (36 soil dosimeters) and Halfa Aljadida (40 soil dosimeters). In each town, holes with different depths were dug and a dosimeter was put upside down in the bottom of each hole. After two months, the detectors were retrieved and chemically etched (30% KOH) at (70 ± 0.1) o C for nine hours. An optical microscope was used to count alpha- track density registered on each detector. The soil radon gas concentration was calculated using the formula (1)(Al-Bataina and Elzain, 2003):

$$C = \frac{C_0 t_0 P}{P_0 t} \quad \text{..................(1)}$$

Where Co is the radon concentration of the calibration chamber (90 kBq/m3), to is the calibration exposure time (48 hours), pis the measured tracks number density per cm on the CR-39 detectors inside the dosimeters used, po is the measured track number density per cm on the detectors of the calibrated dosimeters, t is the exposure time for this survey (1464 hours) for each town.

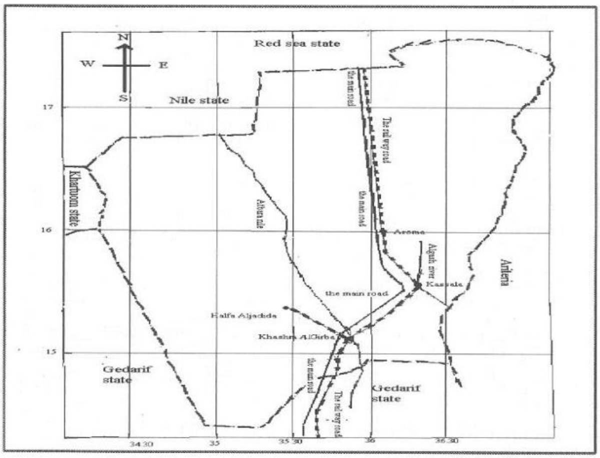

Figure 1. location map of Kassala State

RESULT AND DISCUSSION

Table 1. and Figure 2. show the radon concentration in four towns in the Kassala State. The minimum value of soil radon concentration (452.1 Bq/m) was measured in humid arable soil

In Kassala town. This confirms the fact that the greater the moisture content, the less is the radon content of the soil owing to the decay process during diffusion in soil water region (Fliescher, 1983; Shweikani et aL, 1995). The maximum average value was recorded to be7766.89 Bq/m3, in an area in Kassala town, this area is located along Algash River bank very close to granitic formations of Kassala Mountains hence its soil is classified as being belonged to river terrace soils.

Table l: Radon gas concentration in soil samples

No	Location	N	Min. conce (Bq/m^3)	Max. conc. (Bq/m^3)	c (Bq/m3)	s.d. (Bq/m^3)
I	Kassala	90	452.10	7766.89	2885.98	419.36
2	Aroma	40	1942.99	5727.38	3336.89	500.99
3	Halfa Aljadida	40	1023.56	4145.05	2106.08	397.40
4	Khashm Algirba	36	807.68	5227.03	2169.00	436.99
	All the state	206	452.10	7766.89	2624.49	438.69

N ≡ Number of collected samples.
Min. conc. ≡Minimum concentration.
Max. conc. ≡Maximum concentration.
s.d ≡ standard deviation.

During its flowing period, the Gash River carries large amounts of suspended material which re-sediments as silt clay, sandy clay, and sand and gravel (Ministry of Energy and Mining, 1982). In addition, granites are known to contain high uranium content and thus the originated soils. In most countries the source of indoor radon is the soil or rock adjacent to houses (Akerblom and Wilson, 1982; O' Riordan, 1980).

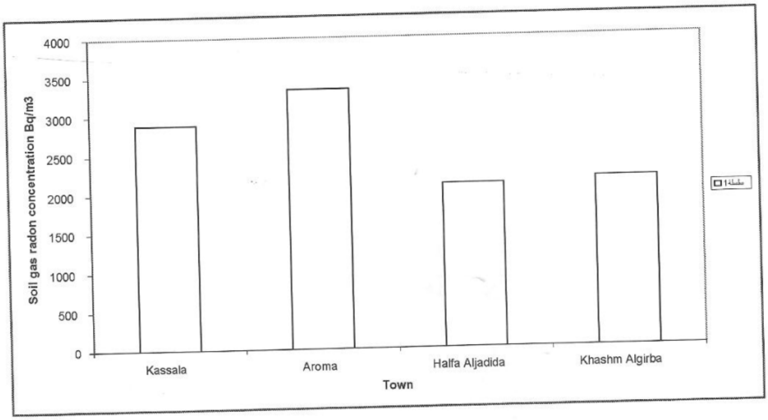

Figure 2. Radon gas concentration in soil at some towns in Kassala State.

The overall average soil radon concentration was found to be 2885.98 Bq/m3 with standard deviation of 419.36 Bq/m3. It was reported that, the soil radon concentration in Korea ranges from 3900 Bq/m3 to 23100 Bq/m3 (Chung et ale, 1998). The survey was held in autumn season where the soil is usually moist compared to other seasons. More radon gas is likely to be emitted from drier than from water saturated soil (Strong and Levins, 1982; T hamer et aL, 1981).

for Aroma town, the concentration falls within the range of 1942.99 Bq/m^3 and 5727.38 Bq/m^3. On the average, there is no any remarkable variation seen amongst different study areas within Aroma town. This reflects that the soil texture is more or less homogeneous. The overall average of soil radon concentration is 3336.89 Bq/m^3 with standard deviation of 500.99 Bq/m^3, which agrees well with values found in Jordan of 3500 Bq/m^3 (Khadier, 1990) and 2935 Bq/m^3(Elzain,2000). The area of Kassala and Aroma is part of alluvium soil transported and deposited by the Gash River in flowing from the Eritrean high lands south of Asmara. The alluvium is thought to be derived mainly from igneous crystalline basement complex, but includes some admixture of sedimentary rocks such as marble and quartzite (Kafeel, 1982). It was reported that, the soil radon concentration in France (Montipellier) which is 2710 Bq/m^3 (Baixeras et al., 1997). It might be useful to recall that, the radon concentration is lower for sandy soils near the saturation state (Baljinder and Virk, 1996).

The minimum value of soil radon concentration in Halfa Aljadida town was found to be (1023.56 Bq/m^3). The higher rates of humidity (during the rainfall period), and the shallower sampling depths (10 cm), may be the cause for the low values in this area. This agrees with the fact that the soil radon concentration decreases near the ground surface (Fukui, 1996).

The variations in soil radon concentration can be highly influenced by metrological factors such as rainfall (Monnin and Seidel, 1989). The maximum value was found to be 4145005 Bq/m^3, at this area in Halfa Aljadida town, the soil is black clayey and the sampling depth was deeper ranging from 30 to 50 cm. It contains lesser amounts of moisture content, lower water saturation fraction at various depths, and located at more elevated area as compared with its surroundings, so the rainfall effect seems negligible. The radon emanation from the soil is known to be related directly to air temperature and wind velocity; and inversely with the barometric pressure, humidity and rainfall (Singh, 1989; NCRP, 1988). It was reported that the water saturation fraction is related directly with radon levels (Strong and Levins, 1982; Thamer et ale, 1981). The overall average radon concentration in Halfa Aljadida soil is 2106.08 Bq/m^3 with standard deviation of 397.40 Bq/m^3, which is lower than that found in Kassala and Aroma towns and falls within the range characteristic of deep soil radon concentration of 1 to 40x103 Bq/m^3 (Albarracfn et ale, 2002).

On location wise, average soil radon concentration at Khashm Algirba town was found to range from 807.68 Bq/m^3 to 5227.03 Bq/m^3. The effect of soil nature is apparent here as the soil is coarse sandy with higher permeability. When the pores in the soil are filled with air not with water, radon will diffuse faster in the case of higher porosity. On the other hand, if pores are filled with water, then this water will decrease the diffusion of radon even if the value of porosity is high (Shweikani et al., 1995). The computed overall town average was 2169 Bq/m^3 with standard deviation of 436.99 Bq/m^3. It is higher than the mean value of soil radon concentration reported from Sosnovy Bor of St Pelerstourg region 1620 Bq/m^3 (Marenny et ale, 1996).

Based on these results we can arrange the State towns in order of decreasing soil radon concentration as follows: Aroma > Kassala > Khashm Algirba > Halfa Aljadida. This seems to be reasonable, because soil in Aroma town (situated at the downstream of Algash River) and Kassala is of silty nature known for its high ion-exchange capacity, which is originated from Eritrean Mountains. The river flows from these mountains with an acute inclination until it reaches Gash-die area near Aroma town. Aroma town is thus constructed on the sedimentary silty soils, which is had been annually carried with river. This makes Aroma soil richer in radioactive elements and contributes strongly in enhancing the concentration values of the town. Also we noticed that, the wind which carries the fine sandy soil from outside Aroma town continuously, may carry the trace elements of radioactive materials to the town resulting in maximizing the concentration value. It was found that, the wind direction and velocity affect the radon concentration (Shweikani et al., 1995; Akber et ale, 1992). It is generally accepted that, the convective entry of radon bearing- soil, driven by small pressure differences between the house and the surrounding soil, is the major radon entry mechanism (Gadgil, 1992). The soil at Khashm Algirba and Halfa Aljadida is of clay type mixed with sand and observed to have higher levels of moisture content. The minimum value of soil radon gas concentration was found in Halfa Aljadida town, this might be due to the type of soil, which is flat black clay soil, with smaller pores. This type of soil saves the rainwater over its surface for many days after the rainfall and this maximizes the values of humidity and the moisture content of the soil. This might be the reason why Halfa has a minimum concentration in the state. The heavy rainfall periods induce a modification of the permeability of the soil and produce a decrease in the radon concentration in the soil (Segovia et al., 1997; Megumi and Mamuro, 1973).

Table 2 depicts the radon concentration obtained with respect to the depth of the dosimeters holes in Kassala town. The sample's depth was ranging from 20-50 cm underneath the surface. On the average, the results clearly indicate direct relationship between radon concentration and the depth ranging from 1569.21 Bq/m^3 with standard deviation of 432.93 Bq/m^3 at a depth of 20 cm to 7654.29 Bq/m^3 with standard deviation of 677.80 Bq/m^3 at a depth of 50 cm. This coincides with previous findings that the maximum radon concentration in the soil is found at 40 cm depth (Fukui, 1996),

Table 2: Radon concentration at different depth in Kassala town.

No	Depth(cm)	N	C(Bq/m^3)	sod, (Bq/m^3)
1	20	6	1569.21	432.93
2	30	67	2204.51	356.81
3	35	4	2413.29	385.47
4	40	10	2424.19	402.82
5	50	3	7654.29	677.80

Table 3 shows the results of radon concentration with respect to the depth of the dosimeters hole in Aroma town. The results clearly revealed increasing concentration with depth from 30 cm

(2338.90 Bq/m^3 with standard deviation of 373.11 Bq/m^3) to 55 cm (3926.73 Bq/m^3 with standard deviation of 496.56 Bq/m^3).

As we know, Kassala and Aroma towns share the same geographical and geological region, with the same climate. The texture of the soil in both towns is silty renewed annually by Algash River falling from Ariterian Mountains.

Table 3: Radon concentration at different depth in Aroma town.

No	Depth(cm)	N	C(Bq/m^3)	sod, (Bq/m^3)
1	30	8	2338.90	373.11
2	35	4	3192.60	527.28
3	40	4	3510.08	412.09
4	45	4	3715.82	695.92
5	55	20	3926.73	496.56

Table 4 shows the results of the radon concentration with respect to the sample's depth in Halfa Aljadida town. The results showed clearly the direct proportionality between the concentration and the depth. The minimum average concentration was found for the samples taken at a depth of 10 cm (1192.72 Bq/m^3 with standard deviation of 254.90 Bq/m^3) and maximum 3903.75 Bq/m^3 with standard deviation of 495.53 Bq/m^3 at a depth of 50 cm.

Depth-wise comparison as depicted in **Table 5** illustrates increasing trend in concentration with depth at Khashm Algirba town, the concentration values range from at 15 cm (1364.92 Bq/m^3 with standard deviation of 276.00 Bq/m^3) to 3970.81 Bq/m^3 with standard deviation of 788.07 Bq/m^3 at 50 cm depths. If we compare between soil radon concentration levels obtained in Halfa Aljadida and Khashm Algirba towns which are located in the same area, it is seen that the corresponding concentrations for each depth is similar in both towns. This may give us an idea about the similarity in soil texture and composi-tion, and climatological factors.

Table 4: Radon concentration at different depth in Halfa Aljadida town.

No	Depth(cm)	N	C(Bq/m^3)	sod, (Bq/m^3)
1	10	5	1192.72	254.90
2	25	5	2171.58	526.46
3	30	12	2415.85	501.67
4	40	12	3017.14	502.64
5	50	6	3903.75	495.53

In all locations correlation between depth profile and the radon concentration is strong (Abumurad ete ale, 1997). The maximum depth considered in this study is 55 cm; further investigations might be needed to consider deeper depths (**Table 6 and Fig. 3**).

Table 5: Radon concentration at different depth in Khashm Algirba town.

No	Depth(cm)	N	C(Bq/m^3)	sod, (Bq/m^3)
1	15	6	1364.92	276.00
2	20	10	1929.03	343.09
3	25	5	2240.05	654.57
4	30	10	2276.63	407.55
5	50	5	3970.81	788.07

Table 6: Radon concentration at different depths.

No	Depth(cm)	N	C(Bq/m^3)	sod, (Bq/m^3)
1	10	5	1192.72	254.90
2	15	6	1364.92	576.00
3	22	16	1749.12	388.01
4	25	10	2205.82	590.52
5	30	97	2308.97	409.79
6	35	8	2802.95	456.38
7	40	26	29.83.80	439.18
8	45	4	3715.82	695.92
9	55	14	5176.28	653.80
10	50	20	3926.73	496.56

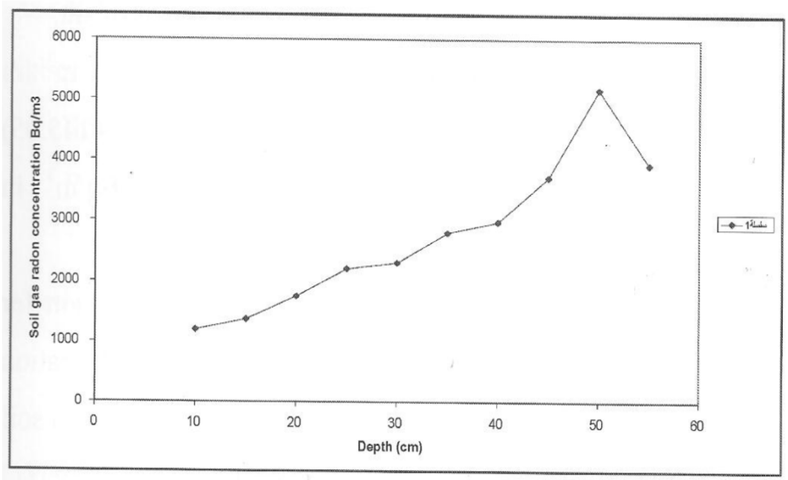

Figure 3. Soil radon gas concentration versus depth.

CONCLUSION

In this study a total of of 206 measurements of soil radon concentration measurements have been done in Kassala State provincial towns in the eastern part of the Sudan namely: Kassala, Aroma, Khashm Algirba and Halfa Aljadida towns. The study was conducted using previously calibrated passive dosimeters containing CR-39. From the results of our study we can conclude that the minimum soil radon concentrations were measured in moist, humid and arable saturated soils. The maximum values of concentration was found in a soil in Kassala town, which is annually renewed by re-sedimentations of silt.

The values obtained were (45210-7766.89) Bq/m^3 in Kassala, (1942.99-5727.38) Bq/m^3 in Aroma, (1023.56-4145.05) Bq/m^3 in Halfa Aljadida, and (807.68-5227.03) Bq/m^3 in Khashm Algirba.

The computed overall average soil radon concentration for all of the State towns is 262449 Bq/m^3 with standard deviation of 438.69 Bq/m^3, which falls within the range typical of deep soil (1 - 40) $\times 10^3$ Bq/m^3 and compares very well with data reported from different geographical regions. The results showed that soil radon concentration increased with depth.

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