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MEASUREMENT OF ^{222}Rn CONCENTRATION IN DRINKING WATER OF MUDIGERE TALUK, CHIKMAGALUR DISTRICT, KARNATAKA, INDIA

E Srinivasa
Department of Physics
IDSG Government College
Chikmagalur

D R Rangaswamy, Sannappa J
Department of Physics
Kuvempu University, Shankaraghatta
Karnataka

ABSTRACT: In the present study, ground water samples were taken from open wells bore wells, hand pumps and public taps at 21 different locations of the Mudigere taluk, Karnataka state, India, were analysed using radon emanometry technique for radon concentration determination. The measured radon concentrations ranged from 0.91±0.5Bq.l^{-1} to 155.46±10.5 Bq.l^{-1} with an average value of 50.19±5.1 Bq.l^{-1}. This study reveals that 85 % of drinking water samples have radon levels higher than the maximum contaminant level of 11 Bq.l^{-1} recommended by EPA. Except at three locations, the recorded radon concentration values were found to be well below the action level of 100 Bq.l^{-1} recommended by WHO. From the measured radon concentrations the effective doses for the population of the region were estimated. The estimated total annual effective dose due to radon inhalation and ingestion is ranges from 2.45 µSv.y^{-1}to 424.41µSv.y^{-1} with an average value of 137.04 µSv.y^{-1}. The total annual effective dose due to bore well water samples at some locations of the studied area is found to be above the safe limit (0.1 mSv.y^{-1}), recommended by WHO and EU Council. It is also found that the dose due to bore well water samples is higher compared to dose due to water from other sources like hand pump, open well and tap water.

Keywords— Radon, Drinking water, Annual effective dose, Emanometry, Ingestion dose

INTRODUCTION

Radiation is a natural part of the environment in which we live and water dissolves the radioactive isotopes in varying degrees. The high concentration of these radioactive isotopes in the environment is a threat to our health. The largest fraction of the natural radiation we receive comes from the radioactive gas radon (^{222}Rn), which disintegrates by emitting alpha particles [1, 2]. Radon is a naturally occurring radioactive gas that is part of the uranium decay series. Radon is present everywhere in the rock, soil, water and air because of the ubiquitous nature of its parent radioactive element uranium in all geological terrains. Alpha particles resulting from decay of radon and its progenies can cause cell and molecular changes that leads to lung, stomach cancer and also other cancers [3, 4].Groundwater dissolves radon from the soil or aquifer and releases certain quantity to air when it comes in contact with it. Because of its gaseous nature, radon can move freely through porous media such as soil or fragmented rock. Radon may permeate from rocks and soil into buildings through cracks in floors or gaps around pipes or cables. Consequently domestic water supplies may have elevated concentrations of dissolved radon. Radon can be released from the water into the air, when inhaled, results in radiation exposure of the lungs [5-7].

The measurement of radon concentration in ground water has attracted considerable attention over the past several years due to the effect of ^{222}Rn and ^{226}Ra on human being health [10]. This is due to the attention directed towards the very high radiation doses which infants and young children can receive due to consumption of water containing radon and radon decay products such as polonium-218 (^{218}Po), lead-214 (^{214}Pb), bismuth(^{214}Bi), and polonium-214 (^{214}Po) for a longer period [8, 9].

When radon and its progeny are inhaled, lung cancer accounts for most of the total increment cancer risk, while ingestion of radon in water is suspected of being associated with increased risk of tumours of several internal organs, primarily the stomach [10]. Radon itself is not responsible for the hazards. Being chemically inert it does not accumulate to a great degree in the body. Primary concern is associated with short lived decay products of radon which produces health hazards to mankind. As the radioactive contamination from the bore well water is high as compared to other sources like lake and river water. From the health, hygiene, and also radiological point of view, these types of studies are very essential for assessment of the doses and health risk resulting from consuming water. In United States, about 168 cancer deaths per year are caused by radon gas present in the drinking water, 89 % from lung cancer caused by breathing radon released from water, and 11 % from stomach cancer caused by drinking radon containing water [11]. The factors that affect the radon content in waters are the geology of the area, bottom sediments, inputs from streams, degree of water turbulence and temperature [12].

The principal objectives of the study were to determine the distribution of radon activity concentrations in public drinking water supplies and to assess their dosimetric implications.

GEOLOGY OF THE STUDY AREA

Mudigere is one of the taluk in Chikkamagaluru district situated in the south western region of the Karnataka state located at a $13^0 18^1$ north latitude and $75^0 49^1$ east longitude. The Western Ghats start just from the outskirts of the city and situated in the Deccan plateau. Nearly 60% of the area in Mudigere taluk is covered by gneiss and rest of the area is occupied by schist formation. The other type of rock formations are migmatites and granodiorite, etc. Weathered fractured and jointed gneiss and schist serves as potential aquifers in the area. The predominant geological formations are charnokite, gneisses & unclassified crystallines, slates, phyllites and schists. The major soil type in the district comprises of Red loamy, Red sandy soil, hilly area soil, mixed red and black soil.

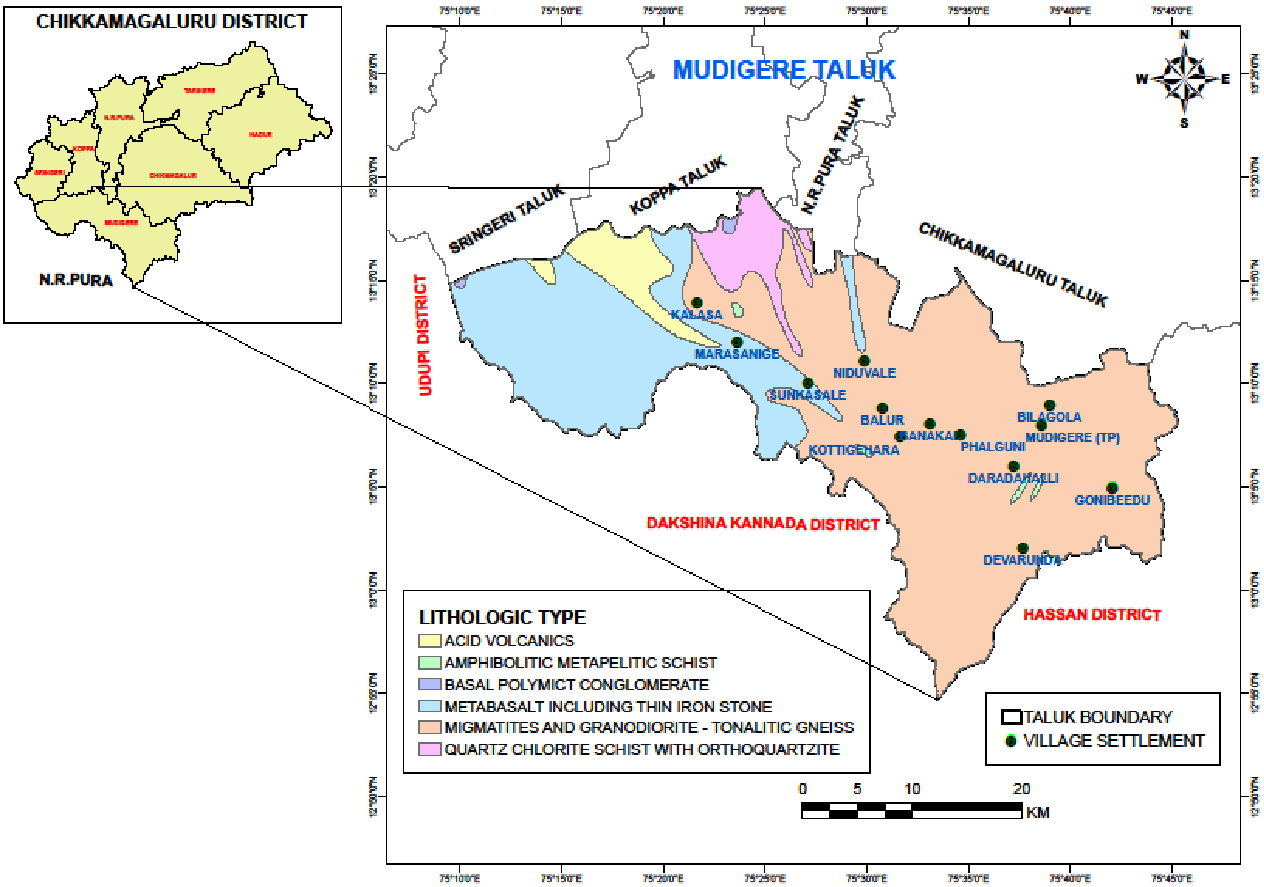

Figure-1: study area map

MATERIALS AND METHODS

A. COLLECTION OF THE WATER SAMPLES AND DETERMINATION OF ^{222}RN BY BUBBLER METHOD

The bore well, open well, hand pump and public tap water samples were collected from 20 different selected locations in Mudigere taluk during August 2016 to November 2017. From each location three samples are taken for measuring radon concentration reproducibility. About 500 ml of water samples were collected in air tight plastic bottle with minimum disturbance. The plastic bottles were filled completely in a gentle manner, so that zero head space was present. Care was taken to see that no air bubbles were seeing inside the container and also to avoid aeration during the sampling processes, which might lead to out gassing. All the collected samples were analysed within 24 hours. The concentration of ^{222}Rn in drinking water was estimated by the Emanometry technique [13]. After collecting the water samples by using the above standard procedure, the samples were brought to the laboratory, about 60 ml of the water samples was transferred into the bubbler (fig-2) by the vacuum transfer technique. The dissolved radon in the water was transferred into pre-evacuated and background counted scintillation cell (fig-3). The scintillation cell was stored for 180 minutes to allow radon to attain equilibrium with its daughters and then it was coupled to a photomultiplier and alpha counting assembly. The radon concentration in ground water samples were calculated using the relation (1) [13].

$$\mathrm{Rn}^{222}\,(\mathrm{Bq.l}^{-1}) = \frac{6.97\times10^{-2}\times D}{V\times E\times(1-e^{-\lambda t})\times e^{-\lambda T}} \qquad (1)$$

Where, D= Counts above background, V= Volume of water (l), E= Efficiency of the scintillation cell (74%), λ = Decay constant for radon (2.098×10^{-6})(s^{-1}), T= Counting delay after sampling (s), t = Counting duration (s).

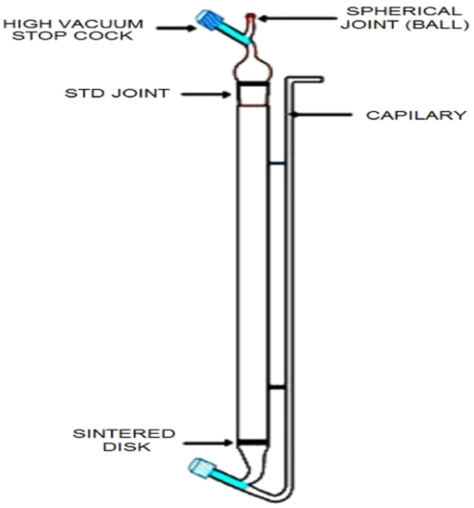

Fig: 2 Radon Bubbler,

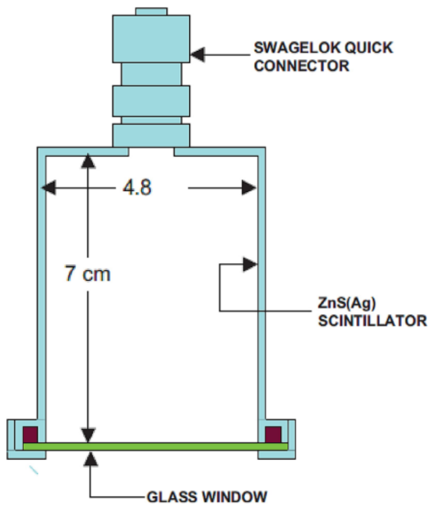

Fig: 3 Lucas cell

B. ESTIMATION OF DOSE DUE TO INHALATION AND INGESTION OF ^{222}RN IN DRINKING WATER

The dose due to ^{222}Rn can be divided into two parts namely, the dose from inhalation and the dose from ingestion. The annual effective doses for inhalation and ingestion from radon in water were calculated by using the parameter established in the UNSCEAR2000 report as [14].

$$D_{In}(\mu Sv\cdot y^{-1}) = A_{RnW}\times C_{aW}\times F\times I\times DCF \qquad (2)$$

Where D_{In} is the effective dose for inhalation, A_{RnW} is the radon concentration in water (Bq l^{-1} or kBq m^{-3}), C_{aW} is the radon in air to the radon in water ratio (10^{-4}), F is the equilibrium factor between radon and its progenies (0.4), I is the average indoor occupancy time per individual (7000 ha^{-1}) and DCF is the dose conversion factor for radon exposure [9 nSv (Bq h m^{-3})$^{-1}$].The ingestion dose is calculated using the following formula,

$$D_{Ig}(\mu Sv\cdot y^{-1}) = A_{RnW}\times C_{W}\times EDC \qquad (3)$$

Where D_{Ig} is the effective dose for ingestion, A_{RnW} is the radon concentration in water (Bq l^{-1} or kBq m^{-3}), C_w is the weighted estimate of water consumption (60 la^{-1}) and EDC is the effective dose coefficient for ingestion (3.5 nSvBq^{-1}), respectively. The dose contribution from this source to the lungs and stomach is calculated by multiplying the inhalation and ingestion dose by tissue weighting factor for lung and stomach respectively.

RESULTS AND DISCUSSION

The distribution of average radon concentrations for all measured water samples of the study area as well as the mean annual effective doses to the stomach, lung and whole body per person for adults have been calculated and presented in the Table 1 and figure 4 and 5. The mean values of radon concentration of all the studied drinking water samples varies from 0.91± 0.5Bq.l^{-1} to 155.46±10.5 Bq.l^{-1} with an average value of 50.19±5.1 Bq.l^{-1}.The higher concentration of radon in bore well water was observed at Baggasagodu of Banakal bore well water sample. This is because the place is in hilly area and these regions are composed by the granites and metamorphic rocks. The lower radon activity concentration in drinking water was observed at Ganganamakki, of Mudigere and Kottigehara bore well water samples. This is due to the groundwater occurs in this area under phreatic condition in weathered zone of gneiss, and under semi-confined to confined conditions in joints and fractures of the formation at deeper level and these regions are attributed by schist, these rocks contains lower activity of radionuclides [9]. In all the studied samples, the higher radon concentration in drinking water was observed in bore well and hand pumps water is possibly because of its greater depth, which allows water to interact with a greater thickness of aquifer and thus more radon is expected in hand pumps and bore wells. The lower radon concentration was observed in tap, tank and open well water as compared to bore well and hand pump water. This is because, during the transfer of bore well water through pipe, the radon gas is desorbed and aeration takes place when it is stored, the tap and tank water are well exposed and radon gas is escaped easily into the atmosphere hence its concentration decreases. The USEPA proposed that the allowed maximum contamination level (MCL) for radon concentration in water is 11 Bq.l^{-1}[15]. This study reveals that 85 % of drinking water samples have radon concentration levels higher than the maximum contaminant level of 11 Bq.l^{-1} recommended by EPA. The UNSCEAR (2008) has suggested a value of radon concentration in water for human consumption between 4 and 40 Bq.l^{-1}[16]. The recorded radon concentration values are compared with the European Commission recommendations on the protection of the public against the exposure to radon in drinking water supplies, European Commission (2001)[17], and WHO (1993)[18], which recommends the action level of radon in drinking water as 100 Bq.l^{-1} for public water supplies. Except 3 bore well water samples, all the recorded values are found to be well below the action level and hence safe for drinking purposes. It was observed that the 50% of the recorded values were well within the safe limit.

In Table 2 radon concentration in drinking water samples of the study area has been compared with the results of similar studies conducted in the other countries as well as in the other cities of India. The results of average radon concentration of 50.19±5.1 in the drinking water samples of this study is slightly higher than the average radon concentration obtained from Shimoga and Hassan district and less than the Tumkur and Bangalore districts, in India respectively.

The World Health Organization [18] and EU Council [17] recommend the determination of reference level of the annual effective dose received from drinking water consumption at 0.1 mSv.y^{-1}. According to WHO [18], if dose is lesser (or equal) than 0.1 mSv.y^{-1}, then, the water is appropriate for drinking purpose and no any additional action is required, on the other hand, if dose is exceeding 0.1 mSv.y^{-1}, then remedial measures are desirable to reduce it. From this study the mean annual effective doses for inhalation and ingestion varies from 2.27 µSv.y^{-1} to 391.76µSv.y^{-1} with an average value of 126.50 µSv.y^{-1} and 0.19 µSv.y^{-1} to 32.65µSv.y^{-1} with an average value of 10.54 µSv.y^{-1} respectively. The estimated total annual effective dose due to radon inhalation and ingestion is ranges from 2.45 µSv.$y^{-1}$to 424.41µSv.y^{-1} with an average value of 137.04 µSv.y^{-1}. The dose contribution from this source to the stomach is calculated and is varied between 0.02 µSv.y^{-1} to 3.92 µSv.y^{-1} with an average value of 1.26 µSv.y^{-1} and similarly the dose contribution from this source to the lung is calculated and is ranged between 0.27 µSv.y^{-1} to 47.00 µSv.y^{-1} with an average value of 15.20 µSv.y^{-1}. The average value is just above the reference level of 0.1 mSv.y^{-1} of WHO and hence do not pose any health problem from radon dose received from drinking water in the study area. The variation of ^{222}Rn concentration and annual effective dose to the public's are shown in Fig 2 and 3.

UNSCEAR has provided mean dose from radon in water. From inhalation the mean radon dose is 0.025 mSv.y^{-1} and from ingestion it is 0.002 mSv.y^{-1} [11]. Comparison of these results indicates that in case of water health risk is mainly from inhalation of radon. From the study, the mean anural effective doses of 126.50 µSv.y^{-1} and 10.54 µSv.y^{-1} due to inhalation and ingestion from radon in water are higher than the mean annual effective doses of 0.025 and 0.002 mSv.y^{-1} of UNSCEAR due to inhalation and ingestion respectively.

Table-1: radon concentration, inhalation, ingestion and total dose in the drinking water samples of Mudigere taluk.

SL NO	LOCATION	SOURCE TYPE	^{222}Rn CONCN (Bq.l^{-1})	INHALATION DOSE (µSv.y^{-1})	INGESTION DOSE (µSv.y^{-1})	DOSE TO LUNGS (µSv.y^{-1})	DOSE TO STOMACH (µSv.y^{-1})	TOTAL EFFECTIVE DOSE (µSv.y^{-1})
1	Kottigehara	Tap	0.90±0.5	2.268	0.19	0.27	0.02	2.45
2	Kottigehara	Open well	12.16±2.3	30.643	2.55	3.68	0.31	33.19
3	Kottigehara	Bore well	38.44±3.6	96.87	8.07	11.60	0.97	104.94
4	Banakal	Open well	10.53±2.4	26.53	2.21	3.18	0.27	28.74
5	Banakal	Bore well	50.04±3.1	126.10	10.51	15.10	1.26	136.61
6	Banakal	Bore well	155.46±10.3	391.76	32.65	47.00	3.92	424.41
7	Bilagola	Hand pump	14.17±1.6	35.71	2.97	4.29	0.36	38.68
8	Sarvodayanagar (C)	Bore well	124.55±12.8	313.87	26.16	37.7	3.14	340.02
9	Krishnapura (C)	Bore well	98.92±6.5	249.28	20.77	29.9	2.49	270.05
10	Handpost Circle (C)	Bore well	64.99±4.5	163.77	13.65	19.7	1.64	177.42
11	Ganganamakki (C)	Bore well	32.51±3.4	81.92	6.83	9.83	0.82	88.752
12	K M Road (C)	Hand pump	30.36±5.7	76.50	6.37	9.18	0.77	82.88
13	Thathkola Road (C)	Bore well	124.00±8.4	313.80	26.16	37.70	3.14	340.02
14	Devarunda	Open well	25.47±1.9	64.18	5.35	7.70	0.64	69.53
15	Gonibeedu	Open well	21.89±1.6	55.16	4.59	6.62	0.55	59.76
16	Gonibeedu	Bore well	56.41±5.8	142.15	11.85	17.10	1.42	154.00
17	Baluru	Tap	8.46±1.4	21.319	1.77	2.56	0.21	23.09
18	Phalguni	Bore well	55.68±8.9	140.31	11.69	16.80	1.40	152.01
19	Marasanige	Tap	16.56±1.4	41.73	3.48	5.01	0.42	45.209
20	Daradahalli	Bore well	46.12±4.2	116.22	9.68	13.90	1.16	125.91
21	Niduvale	Bore well	65.98±5.9	166.27	13.86	20.00	1.66	180.13

Minimum	**0.90±0.5**	**2.27**	**0.19**	**0.27**	**0.02**	**2.46**
Maximum	**155.46±10.5**	**391.76**	**32.65**	**47.00**	**3.92**	**424.41**
Average	**50.19±4.5**	**126.50**	**10.54**	**15.20**	**1.26**	**137.04**

Note: (C) – Mudigere city

Table-2: comparison of radon concentration in water of Mudigere taluk with data obtained in different environs.

LOCATION	RANGE	MEAN	REFERENCE
Bangalore district	55.96 – 1189.30	-	[19]
Tumkur district	9.69 – 299.06	84.09	[10]
Ramanagara	2.96 – 198.54	41.99	[10]
Mysore	4.25 – 435	25.9	[20]
Coastal Karnataka and Kaiga	-	22.8	[21]
Shimoga district	3.10 - 38.50	13.60	[22]
Hassan district	25.25 -60.74	26.50	[2]
Mudigere taluk	0.90 – 155.46	50.19	Present study

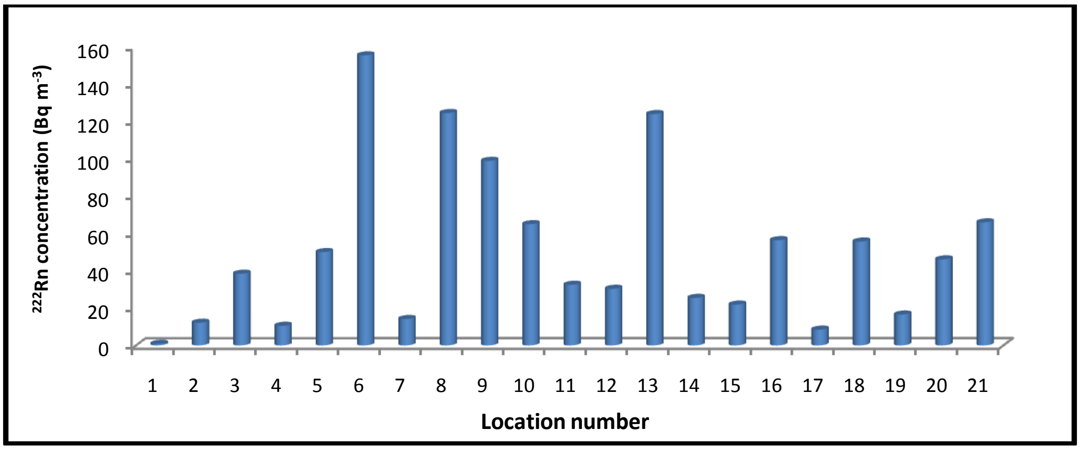

Figure- 4: Radon concentration at different locations.

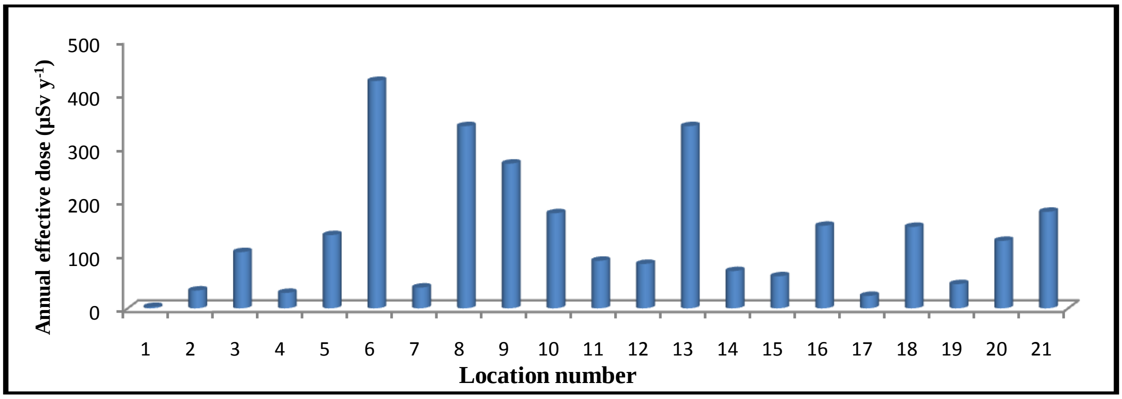

Figure-5: Annual effective dose at different locations.

CONCLUSIONS

The results showed that the radon concentration in drinking water samples of the study area lay in the range from 0.91± 0.5Bq.l^{-1} to 155.46±10.5 Bq.l^{-1} with an average value of 50.19±5.1 Bq.l^{-1}.The obtained results reveal that the ^{222}Rn concentration in open well and tap water is lower than that in bore well water and hand pumps. From this study it is evident that about 85% of samples actually used by the inhabitants of the study area are greater than the EPA recommended level of $11 Bq.l^{-1}$. Except at 3 locations, the recorded radon concentration values in drinking water samples of the study area are within the safe limits recommended by UNSCEAR, WHO and EC. The results show no significant radiological risk for the inhabitants of the studied regions.

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