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Some Studies on Geophysical and Health Physics aspects of Groundwater Radon In Kerala

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ABSTRACT

The measurements of ground water radon (^{222}Rn) content in different parts of Kerala available till date is brought to a uniform scale by cross calibration techniques. High dissolved radon content (> 20Bq/ l) in ground water is observed / inferred in 9 different locations in Kerala, of which five are in Trivandrum district, three in Kollam district and one in Alleppy district. The association of the above results with background radioactivity, mineral springs, seasonal weather changes and human health conditions will be discussed. Spatial variations in ground water radon content in Kerala is found to be correlated with spatial variations in monazite abundance in soil and cancer incidence among human population.

KEY WORDS: Ground water, Radon, mineral springs,radioactivity,cancer incidence

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INTRODUCTION

There are several studies on the radioactive minerals in Kerala especially associated with beach placer deposits.[1] Human health effects of the natural radioactivity in air and water is of main concern here.[2] Among this dissolved radon in ground water (RGW) is important. RGW observations are rare in Kerala. The studies of Prof.Mathai on the radioactivity of rocks and natural mineral waters during 1940's are earliest of that kind in Kerala.[3] It included radon estimation in the water collected from open wells and mineral springs of Trivandrum district. The experimental studies of RGW covering mainly Kollam and Alleppy districts by the Central Ground Water Board (CGB here after) is worth mentioning here.[4,5] Apart from this we have RGW study by Mangalore University[6] covering coastal locations in almost all districts in Kerala and the study by Sheeja[7] covering part of Trivandrum district. There are several published studies of RGW in other parts of India including some in Uranium mines [8 -10]

In this paper we have complied all the available measurements of ground water dissolved radon content in different parts of Kerala spanning a period of more than 70 years. The measurements are subjected to standardization corrections and brought to a uniform scale wherever necessary. We could identify 9 locations of high (> 20 Bq/l) ground water dissolved radon content in Kerala of which five are in Trivandrum district. The geophysical and health physics implications of the above results will be discussed.

MATERIALS AND METHODS

Locations of maximum ground water radon content in different parts of Kerala

In this section we will review RGW measurements carried out in Kerala till date and explore possibilities of bringing them to a uniform scale for comparison and identifying locations of maximum ground water radon content in different parts of Kerala.

2.1 Radon in water measuremts by Prof.Mathai in the Trivandrum district

As a part of a research program of Travancore University Prof. A.O.Mathai (at first as a research scholar and later as a faculty member) of Physics Department of University College in Trivandrum carried out radioactivity studies of rocks and radon measurements in ground water (open wells and mineral springs) in Trivandrum and other locations during the years 1940-1950. [3, 11] Boiling method is used for the Radon -222 measurement. [12] Complete de-emanatiom of the gas is effected by the vigorous boiling of a known volume of the given water sample for a long time. The Rn ^{222} gas is carefully dried and admitted into the ionization chamber of an emanation electroscope.

The period of Prof.Mathai radon measurements is during the years 1942-46. [3, 13] The results of RGW measurements of Prof.Mathai in Trivandrum city, Varkala and other locations are given in Table 1.1 and Table 1.2. Relatively high values of dissolved radon is found by Prof.Mathai is in the Rayon mineral spring in Varkala (34 Bq/l) and in the Uttukuzhy mineral spring in Trivandrum city(33 Bq/l).

Table No. 1.1: " Dissoved Radon content in ground water from different locations in Trivandrum city measured by Prof.A.O.Mathai during 1942-46".

Location	Lattitude	Longitude	Type of water source	Radon content (Bq/l)	Normalized value	Background radiation
Uttukuzhy(oct)	8 29 52	76 57 12	Spring	33.374	1	Low
Uttukuzhy(July)	8 29 53	76 57 13	Spring	27.639	0.83	Low
Manacaud	8 28 18	76 57 06	Open well	14.393	0.43	Low
Pangode	8 30 13	76 58 58	Open well	10.804	0.32	Low
Laboratory	8 30 06	76 56 55	Open well	10.027	0.30	Low
Vanchiyoor	8 29 39	76 56 23	Spring	9.916	0.29	Low
Karamana	8 28 54	76 57 56	Open well	5.513	0.17	Low
Kunnukuzhy	8 30 18	76 56 23	Open well	5.291	0.16	Low
Poojappura	8 29 30	76 58 40	Open well	0.666	0.02	Low

Table No. 1.2: "Dissoved Radon content in ground water from different locations in Varkala and other places (parts of southern Kerala and Tamil Nadu) measured by Prof.A.O.Mathai during 1942-46"

Location	Lattitude	Longitude	Type of water source	Radon content (Bq/l)	Normalised value	Background radiation
i) Varkala						
Rayan spring	8 44 17	76 43 33	Spring	34.632	1	High
Chackratheertham	8 44 12	76 43 30	Spring	14.171	0.41	Medium
Tunnel entrance	8 44 09	76 43 10	Spring	5.439	0.16	Medium
Palace	8 44 04	76 42 32	Spring	3.626	0.10	High
Papanasam	8 43 56	76 43 07	Spring	2.923	0.08	Low
ii) Other locations						
Aryankavu	8 58 00	77 08 35	Well water	9.879		
Manavalackurichi	8 08 79	77 18 08	Monazite beds	<0.37		
Cape Comorin	8 05 17	77 32 18	Well	<0.37		
Aryankavu	8 57 44	77 03 40	Tunnel pee colation	< 0.3		

2.2 Radon in water measurements by Sheeja in Trivandrum district

As a part of her MPhil program in Physics of University College in Trivandrum district Sheeja carried of measurements of radon in water in wells and certain springs in Trivandrum city and neighborhood.[7] The RGW estimates were carried out in collaboration with health physics division of BARC in their environmental radioactivity Labs in IRE near Kochi for two periods (June and November) in the year 1997.

The water samples from different locations are collected in 100 ml polythene air tight bottle. The method used is emanometry method.[9] The apparatus consists of a radon bubbler, scintillation cell (Lucas cell), vacuum pump, hypodermic needle, alpha counting system and photomultiplier. The concentration of dissolved radon was calculated using the relation.

$$^{222}\text{Rn (Bq/l)} = \frac{6.97 \times D \times 10^{-2}}{V \times E \times e^{-\lambda T}(1-e^{-\lambda t})} \quad \text{----------(1)}$$

Where, D = Counts above background(counts/s)

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) and

t = Counting duration (s)

The results of Sheeja measurements of RGW is given in Table 1.3 and Table 1.4. along with values normalized with respect to that of Uttukuzhy mineral spring. These measurements are found to be a gross underestimate of true values of radon in GW in these locations when we compare them with Prof. Mathai's RGW measurements in Trivandrum.

For Uttukuzhy mineral spring in Trivandrum city we have radon measurements by both Prof. Mathai and Sheeja which may help us to find the scaling factor required to correct the later measurements. Seasonal variations are found by studies by Prof. Mathai in the radon content in water from mineral springs in Trivandrum and Varkala. Sheeja found maximum values for radon content in Uttukuzhy spring for November 1997 and we have also radon measurement from an open well near this spring during that period. The average of these values are found to be 0.48 Bq/l (A). Prof. Mathai found maximum value of radon in Uttukuzhy spring during October months of his study (B). The ratio B/A will yield the scaling factor (S_1) for correcting Sheeja's radon measurements in Trivandrum district.

$S_1 = B/A = 33.374/0.48 = 69.53$ (2)

Multiplying Sheeja's RGW measurements in Trivandrum given in Table 1.3 and Table 1.4 with S_1 we have corrected values which is also tabulated there. We can find that the values of radon content in wells of Puthenstreet in Manacaud area within Trivandrum city is inferred to be maximum for Trivandrum district followed by Kumili mineral spring near Neyyatinkara in the Trivandrum district.

Table No. 1.3: " Dissoved Radon content in ground water from different locations in Trivandrum city and nearby places measured by F.R.Sheeja during June 1997"

Location	Lattitude	longitude	Type of water source	Depth (ft)	Radon concentration (Bq/l)	Normailsed value	Corrected value	Background radiation
Kumili Neyyattinkara	9 36 18	77 10 10	Mineral spring	110	0.69	2.464	47.97	Low
Uttukuzhy Statue	8 29 31	76 57 12	Mineral spring		0.28	1	19.47	Low
Puthenstreet Manacaud	8 28 41	76 56 42	Bore well	45	0.23	0.821	15.99	Low
Vanchiyur Malloor raoad	8 29 39	76 56 23	Bore well	200	0.21	0.750	14.60	Low
Sainik school Kazhackuttom	8 34 50	76 52 18	Bore well	220	0.15	.536	10.43	Medium
Sainik school Kazhackuttom	8 34 52	76 52 20	Bore well	160	0.05	0.179	3.48	medium

Table No. 1.4 " Dissoved Radon content in ground water from different locations in Trivandrum city and nearby places measured by F.R.Sheeja during November 1997"

Location	Lattitude	longitude	Type of water source	Depth (ft)	Radon concentration (Bq/l)	Normailsed value	Corrected value
Puthen street Manacaud	8 28 40	76 56 39	Open well	40	0.990	2.302	68.83
Puthen street Manacaud	8 28 40	76 56 39	Bore well	45	0.914	2.126	63.55
Uttukuzhy Statue	8 29 53	76 57 12	Open well	15	0.529	1.230	36.78
Uttukuzhy Statue	8 29 53	76 57 12	Mineral spring		0.43	1	29.90
Kumili Neyyattinkara	9 36 18	77 10 10	Mineral spring	110	0.230	0.535	15.99
Kumili Neyyattinkara	9 36 18	77 10 10	Open well	60	0.12	0.279	8.34

2.3 Radon in water measurements by Central ground water board in Kollam and other districts

As a part of hydrochemistry studies of Central ground water board (CGW hereafter) in Kerala dissolved radon gas measurements in ground water were carried out in different parts of Kollam, Alappuza, Pathanamthitta and Trivandrum districts in southern Kerala. In this study we will not discuss their measurements in Trivandrum district since it is restricted only to a few places.

The water samples were analyzed using RAD7, which is an online monitor for calculating the radon concentration. [4] It is based on the solid state silicon detector. RAD7 is set to wat 250 mode for finding radon in water samples. The removed radon gas is sucked through filter into the inlet and reaches the measured chamber.

Their results are given in Table 1.5. From this we can find that maximum value of RGW is found for Chavara in Kollam district, Karumadi in Alleppy district and Thuvayur in Pathanamthitta district.

Table No. 1.5: "Maximum and average values of dissolved Radon content in ground water from Kollam,Pathanamtitta and Alappuza districts of Kerala measured by Central Groundwater Board in 2015"

District	Average value (Bq/l)	Maximum value	Lattittude	Longitude	Location
Kollam	6.643	25.80	8 59 32	76 31 58	Chavara
Pathanamthitta	1.492	3.04	9 06 24	76 41 39	Thuvayur
Alappuzha	3.371	25.8	9 22 60	76 23 14	Karumadi

2.4 Radon in water measurements by Mangalore University in Coastal Kerala

RGW measurements are carried out Mangalore University in 12 coastal locations covering most of Kerala state .

The water samples from different locations are collected in 100 ml polythene air tight bottle. The method used is emanometry method. The apparatus consists of a radon bubbler, scintillation cell(lucas cell), vacuum pump, hypodermic needle, alpha counting system and photomultiplier. The concentration of dissolved radon was calculated using the relation.

$$^{222}\text{Rn (Bq/l)} = \frac{6.97 \times D \times 10^{-2}}{V \times E \times e^{-\lambda T} \times (1 - e^{-\lambda t})} \quad \text{----------(3)}$$

Where, D = Counts above background(counts/s)

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) and t = Counting duration (s)

Their results are shown in Table 1.6. We can find that these measurements are also gross under estimate of true radon content in ground water in these locations similar to Sheeja measurements in Trivandrum and hence require appropriate scaling corrections. From Table 1.5 we can find the value reported by CGB for RGW in Karunagapally coast is roughly one fourth of the maximum value of RGW in Chavara. Since Mangalore University has reported a value of 0.15 Bq/l for Karunagapally we expect a value of at least 0.6 for Chavara region. The average values of Chavara and Neendakara found by MU may considered as the true value for Chavara which comes exactly 0.6 Bq/l . Let this value be C. The maximum value for Chavara found by Nandakumaran et al be D. The ratio D/C will yield the scaling factor (S_2) for correcting MU radon measurements in different parts of coastal Kerala.

$S_2 = 28.20/0.6 = 47$ (4)

Multiplying the observed radon values of MU given in Table 1.6 we get corrected values which are also tabulated there.

Table No. 1.6: "Dissolved Radon content in ground water in different coastal locations in Kerala measured by Mangalore University during 2012"

Locations	Lattitude	Longitude	Radon concentration (Bq/l)	Normailsed concentration (Bq/l)	Corrected value
Kasargod	12 37 30	74 55 19	0.25	0.714	11.75
Kannur	11 57 35	75 17 13	0.19	0.543	8.93
Kozhickode	11 19 07	75 44 58	0.08	0.229	3.76
Ponnani	11 00 37	75 57 38	0.15	0.429	7.05
Chavackad	10 44 33	76 03 22	0.08	0.229	3.76
Thrissur	10 27 06	76 06 27	0.22	0.629	10.34
Ernakulam	10 05 10	76 15 30	0.06	0.171	2.82
Alappuzha	09 33 48	76 17 45	0.17	0.486	7.99
Karunagappalli	09 15 52	76 25 48	0.15	0.429	7.05
Chavara	09 13 06	76 26 19	0.35	1	16.45
Nindakara	09 10 04	76 27 01	0.85	2.429	39.95
Kollam	08 57 33	76 34 02	1.31	3.743	61.57
Trivandrum	08 32 04	76 55 16	0.03	0.086	4.02
Kovalam	08 25 36	76 5931	0.24	0.686	32.242
Range			0.03-1.31	0.086-3.743	4.02- 61.57

3. Spatial variations in ground water radon, monazite abundance in soil and cancer incidence among human population in Kerala

In Fig 1 we have plotted inferred maximum values of ground water radon (Rp) in different districts in Kerala complied from different observations. For Kollam district we have used measured values at Chavara (Nandakumaran et.al,2015) and for Trivandrum district we have used values of Prof.Mathai for the Chakaratheertham spring in Varkala (Table 1.2)

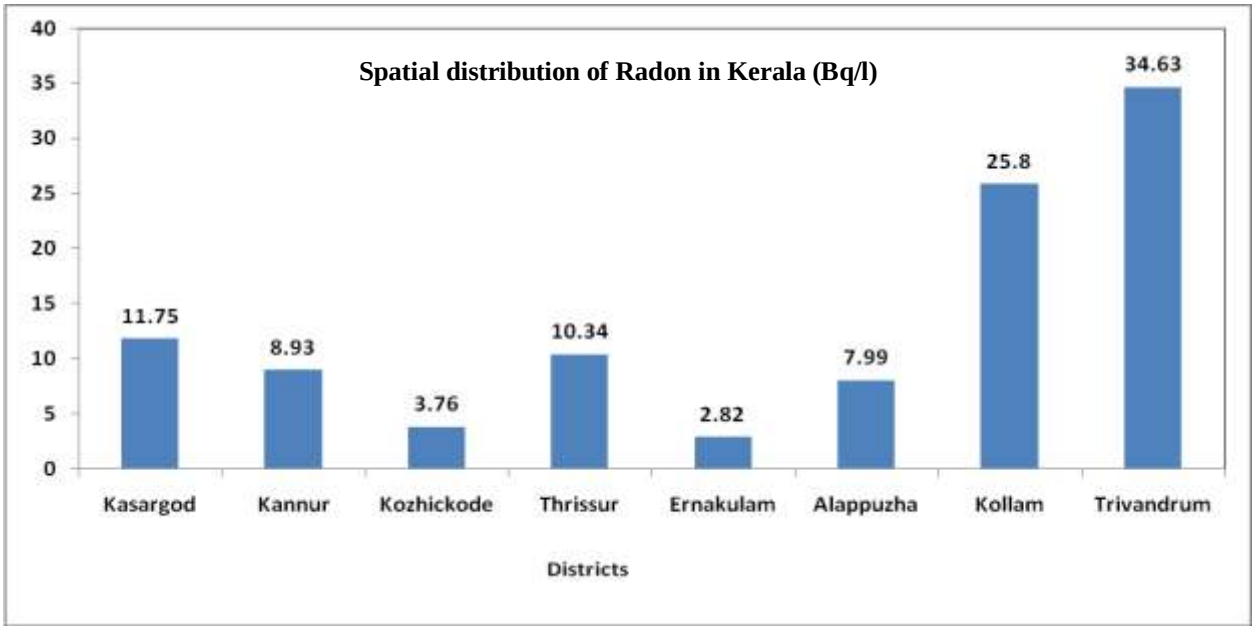

Figure No. 1: Spatial distribution of Radon in Kerala (Bq/l)

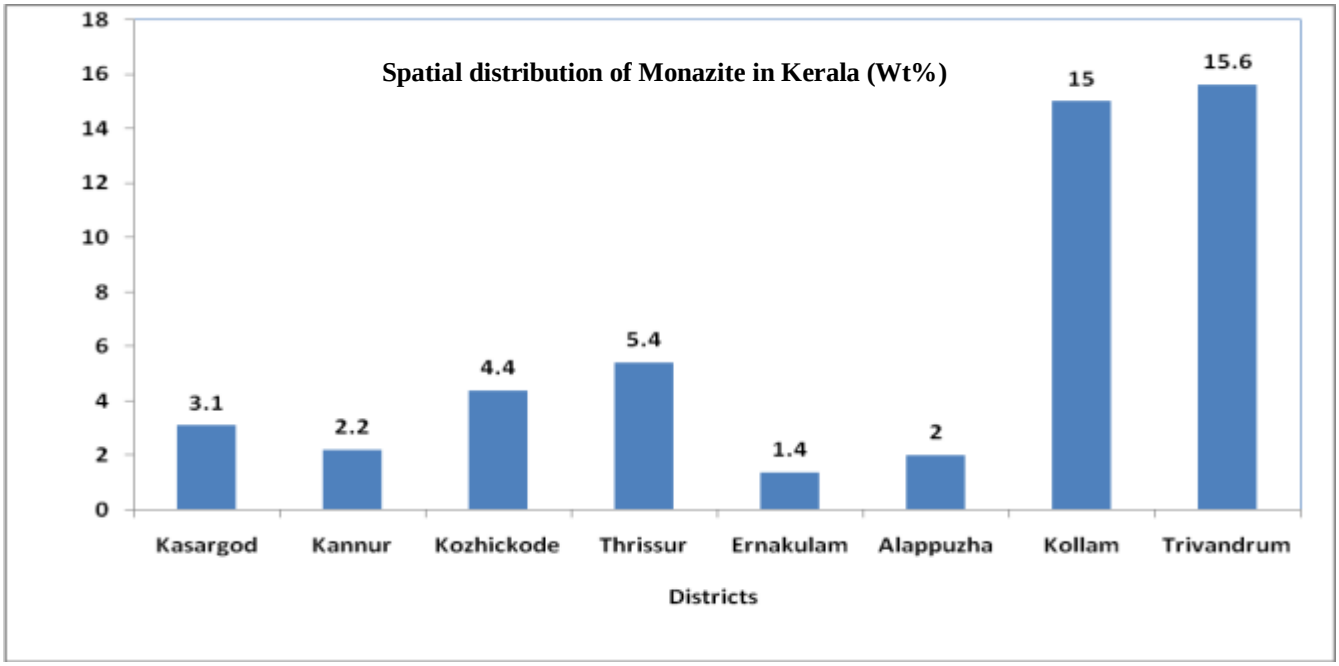

Figure No. 2 : Spatial distribution of Monazite in Kerala (Wt%)

The maximum values of the monazite abundance in soil (Mp) for different districts in Kerala is found from observations published by (Mallick et.al,1987) and the results are shown in Fig 2. It is quite interesting to find good correlation between the parameters plotted in Fig 1 and 2. The following linear regression relation (Fig 3) is found between variations of maximum ground water radon and monazite abundance in soil :-

$$Rp = 1.801\ Mp + 2.199 \qquad (5).$$

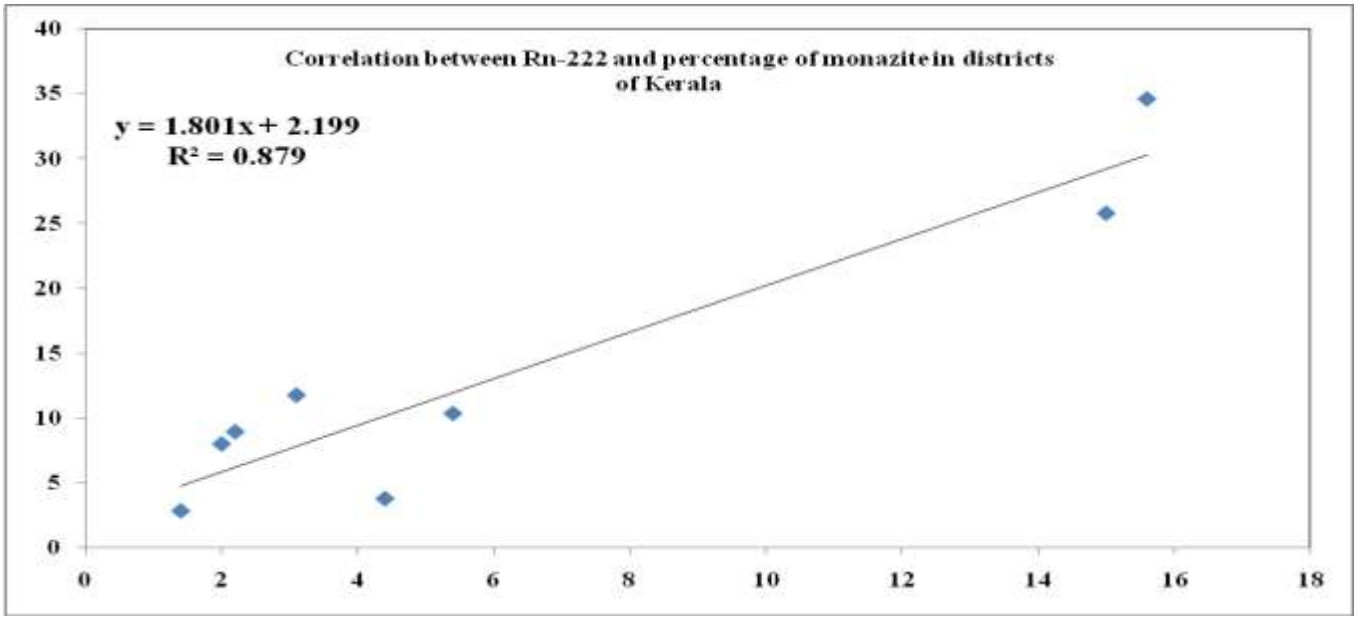

Figure No. 3 : Correlation between Rn-222 and Percentage of monazite in districts of Kerala

We have also collected recent statistics of Cancer incidence among human population in different districts of Kerala and the results are plotted in Fig 4. [23] It is surprising to find that maximum cancer incidence is observed for Trivandrum district which is followed by Kollam district in Kerala and is similar to the inferred ground water radon values in Fig 2. Further we can find that Cancer incidence in these districts are higher than the same found for major cities in India outside Kerala (Fig 5). [23]

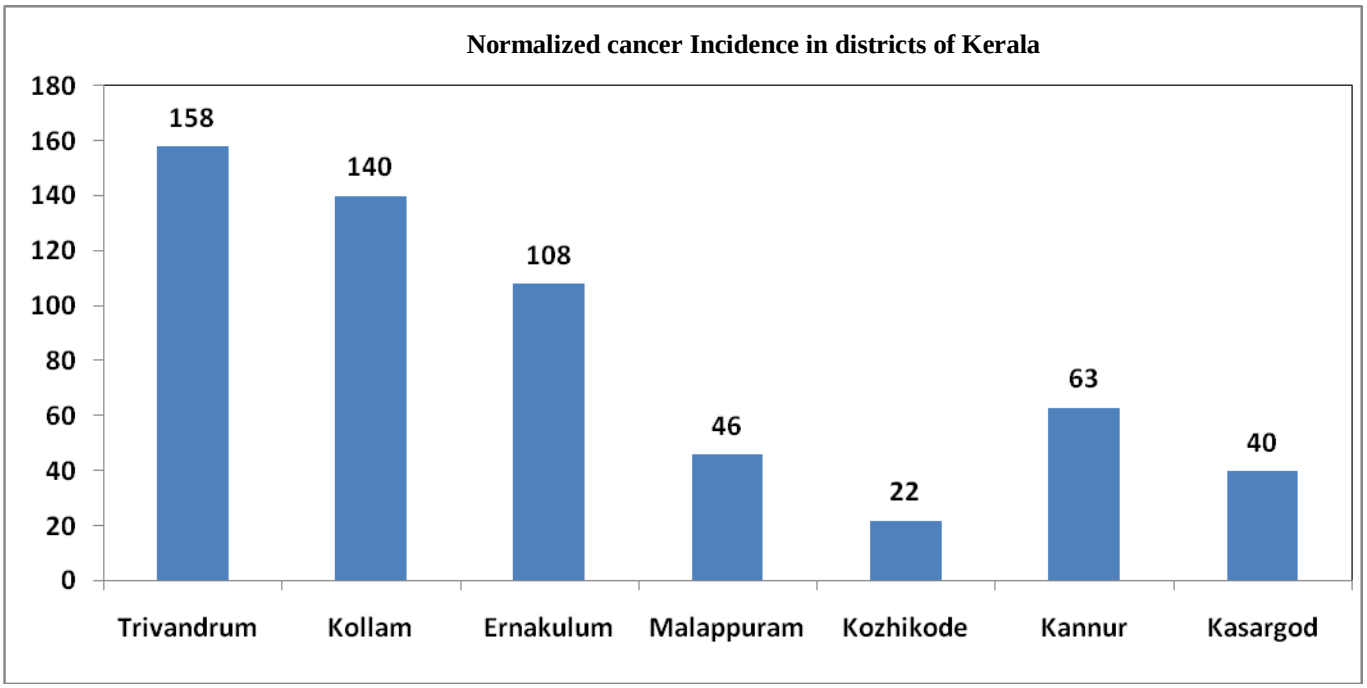

Figure No. 4: Normalized cancer Incidence in districts of Kerala

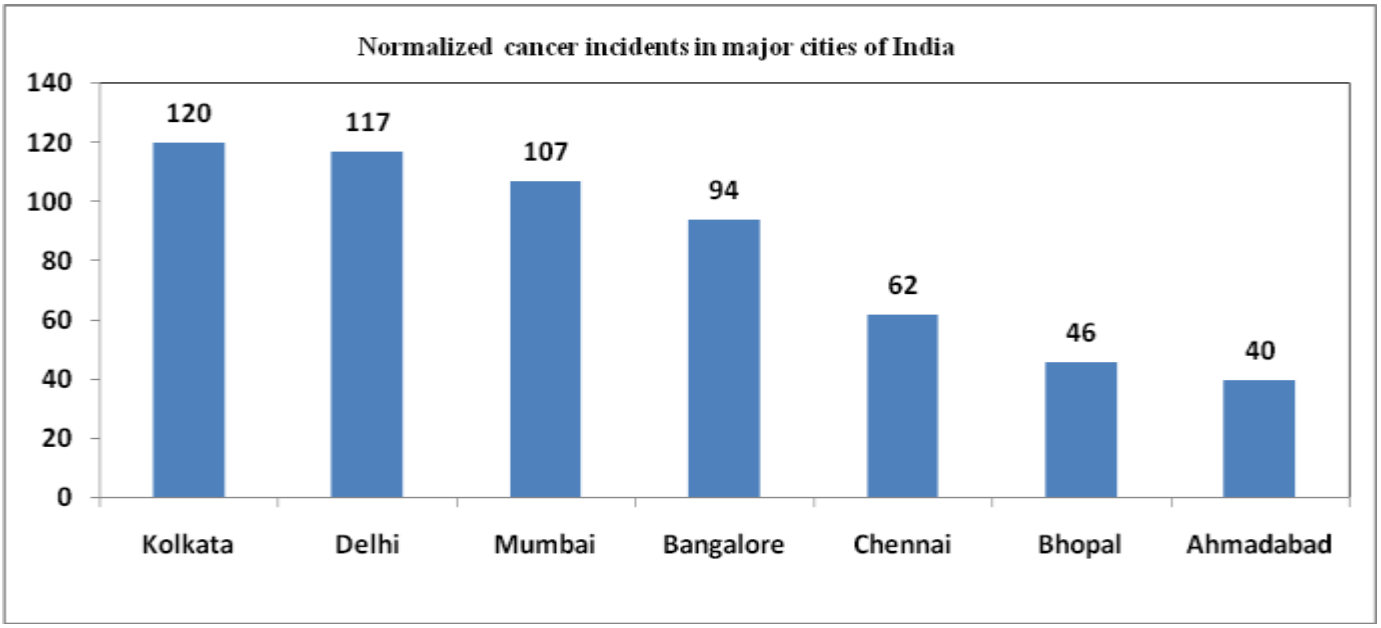

Figure No.5: Normalized cancer Incidence in major cities of India

4 DISCUSSION

One of the main challenges for this study is to bring different RGW measurements in Kerala for the past 70 years to a uniform scale by adopting cross calibration procedures. For Trivandrum measurements Prof.Mathai's measurements in Trivandrum district during 1942-46 is taken as a standard for calibrating later measurements like that of Sheeja in 1997. In this case the accuracy of

standard measurements has to be first justified since it is carried about 70 years ago. The details of Mathai's RGW measuring techniques and their self-calibration procedures for improving its accuracy is available. The boiling method adopted by Prof. Mathai to extract radon gas from the water samples seem to be better than the modern Lucas cell method which uses a vacuum sucking technique.[14] The accuracy of radioactivity detectors used by Prof. Mathai in those days can be known from his estimation of relative uranium and Thorium content in Chavara placer deposits.

Mathai estimated 0.36 % Uranium and 9% Thorium in Chavara Monazite from his experimental studies using a Gold-leaf electroscope which compares well with modern measurements.[15] Isolated RGW measurements carried out by BARC health physics division in Chavara and Aluva also supports the accuracy of Prof. Mathai's measurements in Trivandrum district.[16] To calibrate and re-scale recent Mangalore University RGW measurements in different parts of Kerala, Central Ground water measurements using RAD-7 instrument is taken as a standard which is quite justified.

In Table 1.7 we have given the locations of high RGW in Kerala from the present study. Out of 9 such locations 5 are found to be in Trivandrum district, 3 in Kollam district and and 1 in Alleppy district. Three such locations are found to be in the coastal regions with HBR and beach placer deposits.[17] In Trivandrum district 4 locations with high RGW are found to be in Mineral springs possibly associated with rock radioactivity. From this Table we can find that in these locations the dissolved radon content in ground water vary between 21.5 -68.8 Bq/l. This is not very high when we compare the same with RGW values observed in other locations in India such as Mandya in Mysore[9] and Jaguda mine area in Bihar where average RGW values are above 100 Bq/l.[8]

We could find spatial variations (variations with geographic latitude in particular) of ground water radon content in Kerala correlate well with spatial variations of monazite abundance which is known to contain heavy radioactive minerals such as Th and U. Cancer incidence in different districts in Kerala is also found to correlate with ground water radon and radioactivity mineral abundance in this State. The later relation need not be just casual. It suggests possible health effects of Placer deposits in Kerala.

Due to the popular belief that mineral spring waters may possess medicinal or therapeutic properties they are used for drinking as well as bathing purposes. High radon content is found in mineral springs situated in different parts of India[24-25]. More over several springs are found near pilgrimage and tourist destinations in India. In the international tourist destination Varkala (in Trivandrum district) several mineral springs originating from the Cliff regions are used for bathing

purposes after a dip in the beach area. One such mineral spring (Rayan Spring) is in the list of ground water sources with relatively high radon content in Kerala (Table 1.7) . Utttukuzhy spring in the Trivandrum city and Kumili spring in Neyyattinkara are examples of other mineral springs whose radon content is inferred to be relatively high situated within the Trivandrum district. Radon content screening may be made mandatory for mineral springs found in public places.

Table No. 1.7: "Locations of high dissolved ground water radon content (20 Bq/l) in Kerala and their associated geophysical characteristics"

Serial number	District	Specific location	Observed or inferred RGW in Bq/l	Remarks about the source of GW and radioactivity origin if any
1	Trivandrum	Uttukuzhy Trivandrum City (near Secretariate)	33.3	Mineral spring- rock radioactivity
2	Trivandrum	Puthen steet Trivandrum City	68.8	Open well
3	Trivandrum	Kovalam beach	32.2	HBR area, beach placer deposits
4	Trivandrum	Olathanni - Kumili,Neyyattinkara	46	Mineral Spring
5	Trivandrum	Rayan spring,Varkala	34.6	Mineral spring
6	Kollam	East of Kollam town	61.57	Unidentified
7	Kollam	Neendakara	39.95	HBR area, placer deposits
8	Kollam	Chavara	25.8	HBR area, placer deposits
9	Aleppy	Karumadi	25.8	Open well

Seasonal variations in ground water radon content are observed in different parts of the world. It will be worth examining seasonal changes in radon content inferred for some ground water sources in the Trivandrum. Prof.Mathai found a marginal increase of ground water radon content in Uttukuzhy spring in the Trivandrum city from June to October. The measurements of Sheeja (1997) given in Tables 3 and Table 4 suggest a doubling of radon content in this mineral spring from June to November.

The radon content in Puthenstreet tube well water in Trivandrum city is found to increase by a factor of four during this period. In Figure 6, we have plotted normal values of monthly total rainfall and Figure 7 normal values of number of thunderstorm days in different months observed in

Trivandrum city.[19] High RGW during October/November in Trivandrum compared to June can be related to the following weather phenomena.[11]

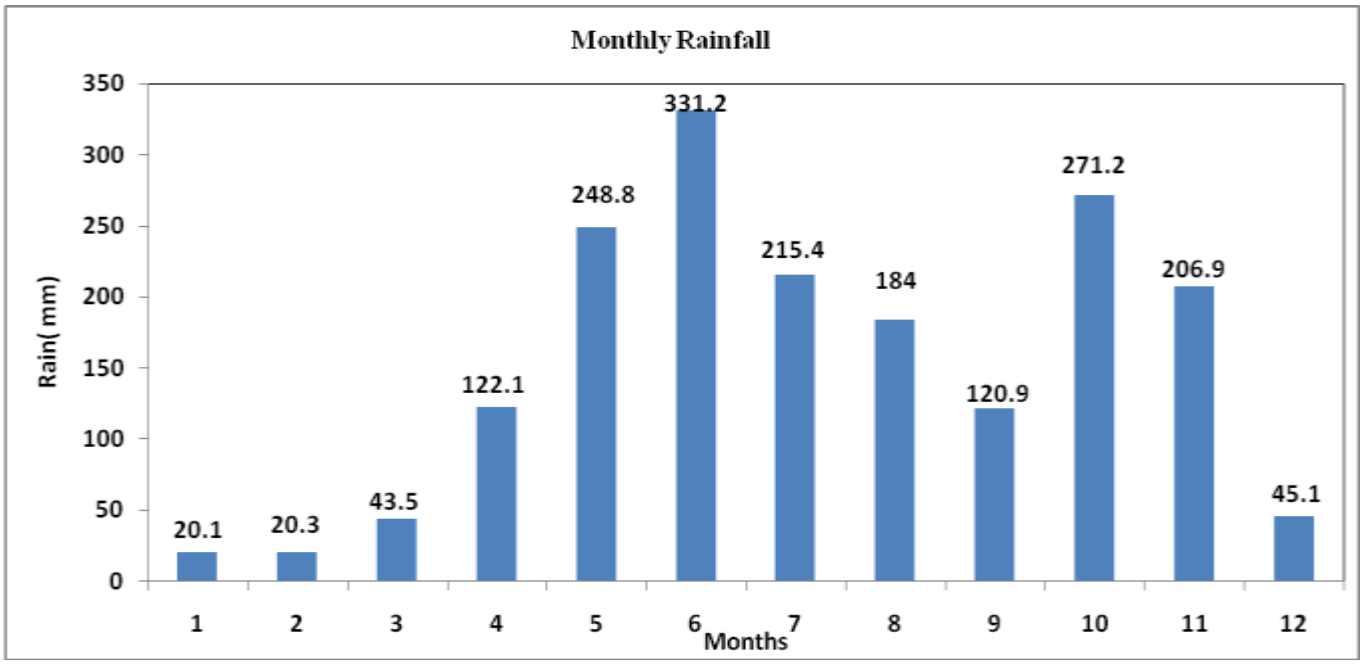

Figure No. 6: Normal Values of monthly total rainfall observed in Trivandrum city

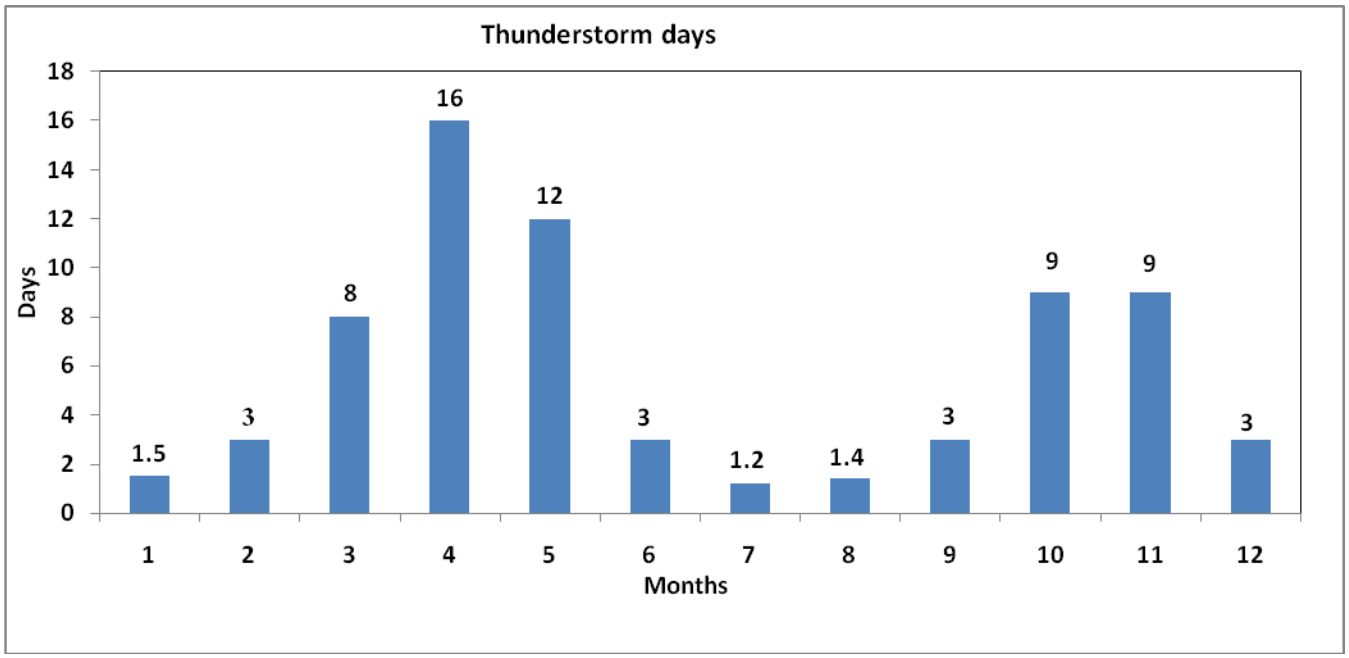

Figure No. 7: Normal values of number of thunderstorm days observed for different months in Trivandrum city

(a) More water recharging after Summer monsoon rains (June-September) in GW locations and dissolving of U/Ra compounds in GW by leaching at its source.

(b) Monson rainfall having dissolved radon content from atmosphere.[20-21]

(c) Thunderstorms and thunder rains are more frequent during October/November in Trivandrum compared to June and this can contain radon from atmosphere where thunderclouds are formed [22].

5 CONCLUSIONS

1. We have collected all the available measurements of dissolved radon content in ground water different parts of Kerala carried out during the years 1942-2015.These measurements are subjected to necessary standardization corrections using cross calibration techniques and brought to a uniform scale wherever necessary.

2. We could identify nine locations of high ground water radon in Kerala (>20 Bq/l) of which five are found to be in Trivandrum district, three in Kollam district and one in Alleppy district.

3. The above results are studied in association with background radioactivity conditions, radon content in mineral Springs and seasonal weather changes

4. Spatial variations in ground water radon content in Kerala is found to be correlated with spatial variations in monazite abundance in soil and cancer incidence among human population.

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