A study on the anomalies of Uranium and Radon concentration in groundwater from hard rock aquifers of Madurai district, Tamilnadu

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Abstract

The hard rocks have negligible primary porosity but are rendered porous and permeable due to secondary porosity by fracturing and weathering. The area chosen for study, Madurai district is also one such complex hard rock terrain constituting Graphite bearing hornblende gneiss and calc-granulites. A total of 39 lithological representative samples were collected from the handpumps throughout the study area in Premonsoon and Post monsoon. The number of samples depends upon the spatial distribution of lithology in the study area. The Uranium was analyzed by the ICPMS. RAD7 was been used for monitoring Radon concentration in water. The Radon was analysed for Post monsoon only. The Maximum value of Uranium observed in the study area is 113 ppb in Premonsoon and 79.85ppb in Post monsoon. The highest concentrations were observed as 60Bq/L in granitic terrains in north eastern part of the study area. In the study area the higher value is noted in the northeastern part of the study area for both seasons where it is predominant by the granitic terrains and lineament are present. The permissible limit for the Uranium in Groundwater is 15ppb (WHO, 2004). In the study area few samples from Fissile hornblende biotite gneiss and from Granite exceeding the Permissible limit in both seasons respectively. The Correlation between Uranium and radon indicate the Uranium may be the reason for evolution of radon in groundwater. Uranium is correlated with HCO_3 indicates the weathering plays a dominant role in dissolution of Uranium minerals to groundwater.

Keywords: Groundwater, Uranium concentration, Radon levels

1. Introduction

U is the primordial radionuclide with 4.5X 10^9 years of half-life. It is present in a traceable amount in all types of rocks. The concentration of Uranium in groundwater depends upon the geological formations that vary from place to place and also depends on the mineralogical and geochemical composition of the soil and country rocks. U in groundwater helps to understand the age of water, groundwater flow and mechanisms of geochemical reactions. U in groundwater is mainly controlled by the pH, oxidation reduction potential and other complexing agents [1].

Rn is the only radioactive gas produced naturally in the earth. It has a half-life of 3.8 days. It is used to detect the geophysical events like earthquakes and Valconic eruptions, Groundwater recharge and discharge [2, 3, 4]

The U and Rn in ground water mainly depend on the fractures, their degree and the angle of inclination to the bedrock [5].Much attention should be paid to the radionuclides in groundwater because the U affects the Kidney and Rn causes the lung cancer. Many studies have been carried out in worldwide to know about the toxicity of the radionuclides [6-8] Natural U and its daughter products in groundwater are often related with the presence of granitic rocks [9,10].

The chosen study area Madurai district is the crystalline hard rock region.Hence the quantum of availability of groundwater is less.Few studies have been carried out in Madurai district to delineate surface and groundwater quality deterioration [11]; impact by lithology and land use pattern for the change in groundwater quality, hydrogeochemical processes using factor analysis [12-14]. The groundwater is a main source of drinking and domestic purpose in the region. The higher amount of U in the Madurai district has been reported by the Pandey and Krishnamoorthy [15] in the rocks. Hence an attempt has been made to understand the toxicity of the U and

Rn in groundwater and variations of U in different seasons.

2. Study area

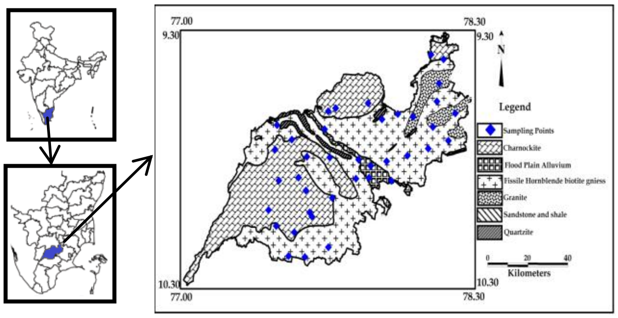

Fig.1 Lithology map of the study area with location and sampling points

The study area is situated near the southern part of the western ghat of Tamilnadu. The main river system that drains the study area is Vaigai. The major geological formation of the regions is an Archaean group of rocks with the Quaternary formation along the river course (Fig.1). The average annual rainfall is about 905mm per annum. The study area is chiefly a hard rock region except along the river course. The major lithological units are Fissile hornblende biotite gneiss, Charnockite, Granite, Quartzite and Flood Plain alluvium.

The study area is predominantly of agricultural practices. The topography of the study area is undulating plain, elevation varies between 160 and 1400 m above mean sea level. The granite quarries are situated in the northern part of the study area. The groundwater is extracted from the weathered part of the rocks, fissures, fault and joints through dug and bore wells. The Tungsten mineralization (Skarn type) in Calc-granulites associated with Neoproterozoic granites in the Karungalakudi area were also reported in the study area [16].

3. Methodology

Totally 78 samples were collected with respect to the lithology for Premonsoon(PRM) and post monsoon (POM) respectively. 15samples from Fissile hornblende biotite gneiss, 16 from Charnockite, 4 from Granite and Flood plain alluvium (Table.1). The pH, EC, Temperature was analysed in the field using hand held instruments (Eutech instruments). The major ions like Ca^{2+} and Mg^{2+} analysed by Titrimetry, Na^{+} and K^{+} by Flame photometer (CL 378); anions, Cl^{-} and HCO_3^{-} by Titrimetry, SO_4^{2-}, PO_4^{-} and H_4SiO_4 by Spectrophotometer (SL 171 minispec). Sampling and analysis was carried out using standard procedures [17].

U measurements were made using a Perkin-Elmer Sciex® ELANTM 5000 ICP-MS spectrometer. 100 mg $L^{-1}$of Uranium Stock solution was prepared from $UO_2(NO_3)_2 \cdot 6(H_2O)$ 99.999%. 10 mg $L^{-1}$of Rh solution was used as an internal standard and it was prepared for $RhCl_3 \cdot 3H_2O$ 38%. In both cases, ultrapure HNO_3 and high purity water of 18.2 MΩ. cm resistivity, obtained from a MilliQ system were used.

RAD7 procured from Durridge Company USA has been used for monitoring Radon concentration in water. The method employs a closed loop aeration scheme whereby the air volume and water volume are constant and independent of the flow rate. The air recirculates through the water and continuously extracts the radon until a state of equilibrium develops. The RAD-H_2O system reaches this state of equilibrium within about 5 minutes, after which no more radon can be extracted from the water. During the five minutes of aeration before the state of equilibrium, more than 95% of the available radon is removed from the water.

4. Results and discussion

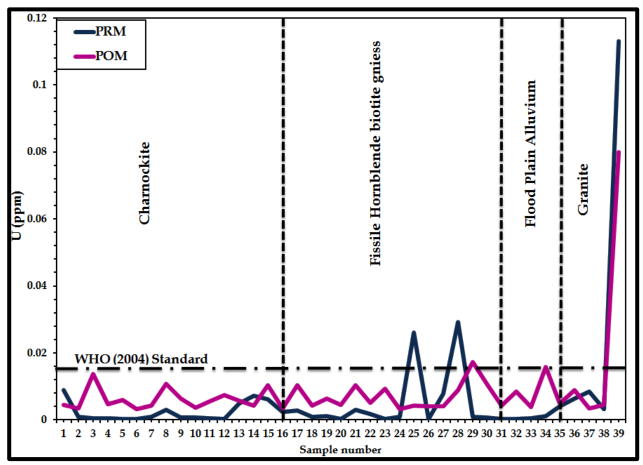

Fig.2 Seasonal variations of U in groundwater samples

Table.1 Maximum, Minimum and average values of different parameters

		U (ppb)	pH	EC (µs/cm)	Temp (^{0}C)	HCO_3 (ppm)	Rn (Bq/l)
PRM	Max	0.11	7.90	2900.00	36.50	439.20	-
	Min	0.00	6.60	580.00	26.50	170.80	-
	Avg	0.01	7.40	1116.23	31.90	288.11	-
POM	Max	0.08	7.83	5218.75	33.50	435.13	60.00
	Min	0.00	6.30	651.56	29.80	185.40	0.10
	Avg	0.01	7.20	1852.82	31.59	274.44	7.90

In the study area 2 samples from Fissile Hornblende biotite gneiss and 1 sample from Granite are above the permissible limit of 15 ppb WHO [18] in PRM and 1 sample from Fissile hornblende biotite gneiss, Flood Plain Alluvium and Granite falls above the permissible limit (Fig.2). The Kidneys and bones are the major locates for the accumulation of uranium in the body [19] and skeleton is the major site for the long term storage of Uranium [20]. The concentration of Uranium in the body the 80 percent is excreted in Urine and faeces, 10% deposited in the kidneys and 10% are deposited in the skeleton [21]. The study by Kurttio et al. [22] suggests that chronic uranium exposure in the human is associated with increases in blood pressure. The proximal tubules within the kidney are the structures mainly damaged by uranium [23]. Bones are the secondary target organ of uranium toxicity and since the majority of absorbed uranium is stored in the bones. Even lower concentration of Uranium in drinking water also causes the nephrotoxic effects [24].

The USEPA[25] standard limit for the radon in groundwater is 11.1 Bq/l. 3 samples from Fissile hornblende biotite gneiss, 1 sample from Charnockite and granite respectively are above the permissible limit. Radon exists as a gas and dissolute in the groundwater and high exposure of long time radon increases the development of lung cancer [26,27]. There is a strong link between exposure to radon and the occurrence of lung cancer. The part of the body that receives the highest dose of ionizing radiation is the bronchial epithelium, although the extra thoracic airways and the skin may also receive appreciable dose [23]. Akerblom [28] discusses that increased incidence of childhood leukaemia, lung and possibly gastric cancers in users of radon-rich groundwater.

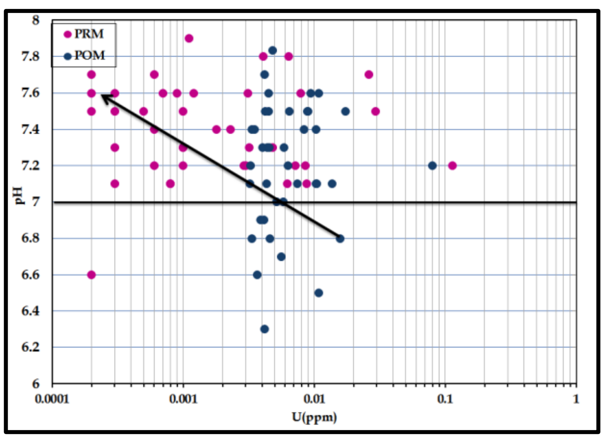

Fig.3 Scatter plot of U with pH of different seasons

U decreases with the increase in pH as observed by Ioannidou [29]. Uranium concentration in PRM and POM has different ranges of pH indicating that the pH may be governing factor for the distribution of U (Fig.3). The higher concentration of U is observed in the near neutral pH.

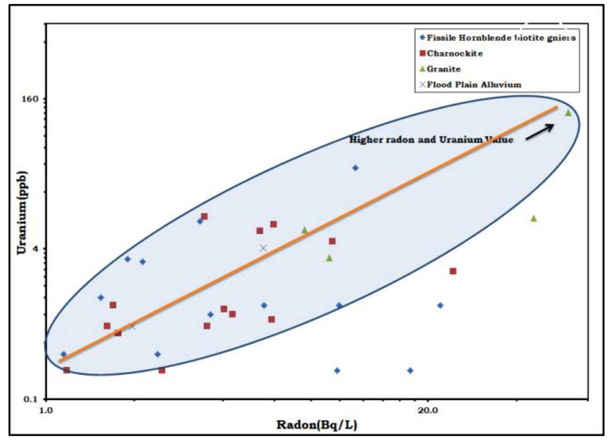

Fig.4 U Vs Rn in POM of groundwater samples

The higher concentration of U has higher concentration of Rn in same location (Fig.4).The concentration of Uranium might have been originated from the zones of Uranium minerals and leaches to the groundwater by the rock water interaction of the host rocks and thus during decay the radon concentration also dissolves in the groundwater , it's also advocated that the primary source of radon is geological bedrock [30]. It's also noted that almost all samples with high Uranium concentration has higher concentration of Radon. Hence the Uranium is the main source of radon in groundwater [31].

The spatial distribution of the higher concentration of Uranium and Radon is observed in the northern part of the study area where the granites are predominant rocks in these regions. The order of dominance of Uranium and Radon in groundwater is

Uranium: Granite> Charnockite> Fissile Hornblende biotite gneiss> Flood Plain Alluvium> Quartzite.

Radon: Granite> Quartzite> Charnockite > Fissile Hornblende biotite gneiss> Flood Plain Alluvium.

Many studies have reported in the granitic terrains with higher concentration of Uranium and radon in groundwater [24,29,32]

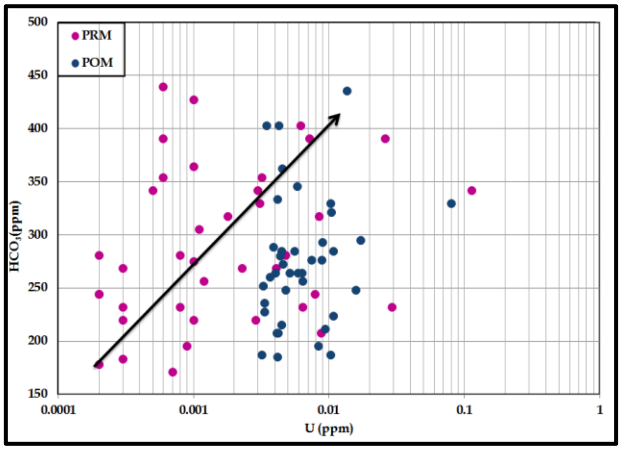

Fig.5 U Vs HCO_3 of groundwater samples of different seasons

U increases with increase of HCO_3 concentration in groundwater. The plot shows that U is highly correlated with HCO_3. The ionic concentration of groundwater in the study area is Cl, HCO_3 and Ca. The weathering is the dominant processes in northern part of the study area [13]. Hence HCO_3 plays a dominant role in U concentration in groundwater.

Table.2 Correlation matrix of different parameters for POM

	pH	EC	Temp	U	Rn
pH	1				
EC	0.0	1			
Temp	0.2	0.0	1		
U	0.0	0.6	0.0	1	
R	-0.2	0.2	0.0	0.7	1

The good correlation exists between U-EC, U-Rn suggests that residence time of groundwater also increases the U concentration in groundwater [29] and U may be probable source for Rn in groundwater.

5. Conclusion

There is a seasonal variation in concentration levels of U which is observed in granitic terrains in both seasons. pH decreases with increase in U suggests that pH may be the governing factor for U in groundwater. HCO_3 has enhanced the mobility of U in groundwater of hard rocks, where the atmospheric interaction is low. The higher concentration of U and Rn is observed in same location resembles that U may be source for Rn in groundwater. The seasonal variation may be due to the precipitation, weathering and leaching processes occurred in the bed rock of granite. The consequences of this processes lead to the high U concentrations in water. Further work is needed to predict the complete processes behind the variations in higher concentrations of U.

Acknowledgments

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