UNDERSTANDING GROUNDWATER SYSTEM FOR ITS SUSTAINABILITY*

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EXTENDED ABSTRACT

Understanding the dynamic behaviour of groundwater system for its sustainability necessitates information and evaluation of aquifers, acuicludes, hydraulic head distribution in space and time, evaluatiŏn of aquifer parameters source and origin of groundwater, recharge processes and recharge rate, interplay between aquifers, interaction between surface and groundwater, residence time and flow rate, hydraulic barriers and preferred path etc. Isotope and Geochemical tracers play a vital role in understanding the groundwater system. They have proved valuable during the last three decades all over the globe, especially in the semiarid and arid regions. The hard rock aquifer system is much more difficult to understand due to inhomogenities and complexities in the geological system. In the lecture delivered, an attempt was made to provide new insights to understand the hard rock aquifer with respect to: (1) Natural recharge processes, source and dynamics of groundwater; (2) Development of new methods of estimation of artificial recharge and (3) Radon/ helium emanometery as atool for better siting of successful wells.

Natural Recharge Processes in Hard Rock Areas

Tracers have proved themselves to be of immense use in assessment of groundwater resources. The piston flow model discovered by Zimmerman et al. (1965) was found to be applicable in alluvial tracts of Gujarat (Sukhija and Rama, 1973; Sukhija and Shah 1976) and Utter Pradesh (Datta et al. 1980). However, recently it has been established that in the hard rock aquifer system this model is not valid as there occurs substantial preferential flow through macro-pores and fractures. The integrated use of tracer methods like envirommental chloride, injected tritium and environmental tritium has provided evidences as well as evaluation of recharge though macro pore and fractures/ fissures. It has been shown (Sukhija et al. 2005) that preferential recharge (Table 1) could account for 25 to 75 percent of total recharge in the consolidated sediments and granites/ gneisses respectively. However, studies using the injected tritium method in the hard rock provide only minimum value of recharge based on piston flow model.

Table 1. Recharge ranges for piston flow and preferential flow process in three studied geological provinces

Formation	Piston flow recharge range (average) (mm)	Total recharge range (average) (mm)	Preferential flor recharge range (average) (mm)	Preferential flow recharge (% of total recharge)
Consolidated (Granites)	20-40 (30)	70-170 (120)	50-130 (90)	75
Semi-Consolidated (Sandstone)	170-30 (235)	260-440 (350)	90-140 (115)	32
Unconsolidated (Alluvium)	13-66 (39.5)	13-50 (31.5)	-	-

Source, Origin and Dynamics of Groundwater in Fractured Granites and Gneisses

With the objective of understanding source, origin and dynamics of groundwater in the granitic areas, a study carried out on the 40 groundwater samples collected around Hyderabad from the depth varying from 50 to 200 m were analysed for ^{18}O, Cl and ^{14}C concentrations. The relation ship between the uncorrected ^{14}C ages and ^{18}O of groundwater samples indicated three distinct groups: Group I: Samples with higher ^{14}C age (1600 to 5600 yr BP) and $\delta^{18}O$ (-3.2 to -1.7‰) indicating flow through extensive sheet joints but recharged through top weathered zone. Group II indicated younger water (with ^{14}C age < 1000 yr BP) and $\delta^{18}O$ (-3.0 to -1.2 ‰) recharged through top weathered zone but does not travel significant distance and groundwater is extracted out. Group III with relatively positive $\delta^{18}O$ (-0.3 to + 1.7 ‰) and younger water ages, such water are recharged through surface water bodies. A similar conclusion was drawn using chloride and ^{14}C age data, thus confirming three different groups of recharge sources and distinct groundwater movement through

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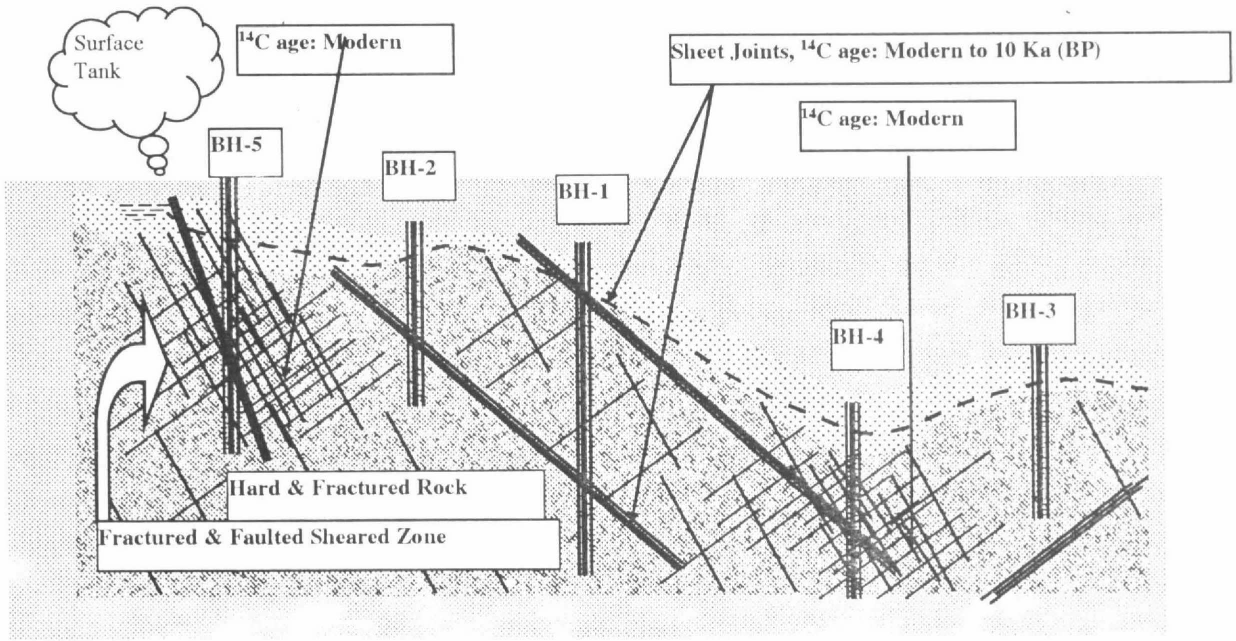

Fig.1. A conceptual hydrogeological model evolved to elucidate various recharge processes and flow mechanisms in the studied fractured hard rock aquifers, based on varying ^{14}C ages, chloride and $\delta^{18}O$ contents of groundwater. Wells like BH-1 and BH-2 get recharged from distant souces and water moves through weathered zone and sheet joints resulting in quite large residence times of groundwaters. Wells like BH-3 are characterized by young ^{14}C ages due to low turnover time, and relatively high chloride concentration in comparison to BH-1 and BH-2, resulted due to natural recharge from thick weathered zone. Groundwaters being recharged from surface water bodies connected through intense fracture network are characterized by young ^{14}C ages and positive $\delta^{18}O$ values are represented by wells like BH-5. The groundwaters in the valley (low lying) areas characterised by thick weathered zone, intensive fracturing in the subsurface, and minimal lateral flow of groundwater are represented by wells like BH-4 which possess young ^{14}C ages and light levels of chloride due to mixing of waters from subsurface contaminant sources (soak pits, drainage lines etc.).

sheet joints (Sukhija et al. 2005). Based on these groups, a conceptual hydrogeological model was evolved (Fig.1)

Development of Chloride Mass Balance Method for Estimating Artificial Recharge

Artificial recharge though percolation ponds has been the most popular method in the hard rocks of India for augementing groundwater in view of the limited natural recharge (Sukhija et al. 1996) and increasing groundwater demands. However, the efficiency of such structures has been debated and this necessitated the development of a more reliable method. Sukhija et al. (1997) developed a new tracer method based chloride mass balance of water in the tank. Percolation fractions computed using the chloride mass balance method for the tanks located in granites, basalts and sandstones showed that the tanks situated in sandstones are most effective (Tablle 2) and secondly comparing the tank percolations in same climatic conditions but in different geological strata showed that geology had greater role than climatic conditions. It was noted that there was decrease in the efficiency of the tank with age (due to silting). Further if

Table 2. Average percolation efficiencies of studied percolation tanks determined using chloride mass balance method

Tanks	Percolation Efficiencies
In Granites	
Kalwakurthy	49
Singaram	35
In Basalts	
Lakanka	28
In Sandstones	
Saper	60

there are more number of bore wells in the downstream side being used for with drawing groundwater, the efficiency is better due to "capture recharge". Thus the analysis of various controlling factors was possible due to more reliable, simple and sensitive chloride method.

Soil Gas Emanometery : A Tool for Delineation of Potential Groundwater Fractures

To site a successful bore well in hard rock area is a challenging task. Conventional geophysical method like resistivity are not adequate as it is found that success rate is no better than 60-70 percent, Thus there is need to develop alternate methods for delineation of fractures in the hard rock areas. There are few earlier attempts (Banwell et al. 1988; Pointet, 1989; Gascoyne et al. 1993; Reddy et al. 1996; Lachassagne et al. 2001). A recent study by us (Reddy et al. 2005) has shown promise for the soil gas Radon emanometery. Radon concentration measurements carried out in grid fashion (50 m) on soil gas samples from 60 cm depth in three transects (KB Tanda, Mohbatnagar and Siglipuram) in the Maheswaram watershed yielded distinct anomalies. Later the deeper measurements (160 cm) at close interval (10 m) confirmed the presence of radon anomalies, and Helium measurements at 160 cm depth also corroborated the radon anomalies. The testing of the hypothesis that the sites with higher radon concentration may be associated with potential groundwater fractures was carried out by drilling wells on the anomalies as well as off the anomalies. Table 3 shows that successful high yield bore wells are associated with higher radon concentration. Thus there exists promise of radon emanometry method for delineation of fractures, which however has to be established on firm footing by extensive radon field measurements and drilling.

Table 3. Bore wells drilled based on the Radon survey

Village	Radon conc.	Well no.	Well depth (m)	Discharge during drilling (lps)
K.B. Tanda	2800 cpm	MW-1	91.5	4.5
	1000 cpm	OB1-1	45.75	1.0
	600 cpm	OB1-2	45.75	No water
	500 cpm	OB1-3	45.75	No water
	500 cpm	MW-2	64.0	0.5
	500 cpm	MW-3	55.0	No water
Sigilipuram	2200 cpm	MW-4	91.5	0.5

Conclusions

For sustainable management of groundwater resource, understanding of the groundwater system is not only prerequisite but also very vital. During last few decades many new concepts and new techniques in the field of isotopes and tracers hydrology have been added to the arsenal of the hydrogeologists. The concepts of piston flow, preferential flow etc. have provided new insights to the understanding of the recharge processes and led to the development of new methods of evaluating groundwater recharge and aquifer potential. For development of groundwater resources in the hard rock areas, besides geophysics, the use of radon has been studied and potential of the method is seen in siting high yield bore wells. For augmenting the depleting groundwater resources, through artificial recharge has been in vogue, new techniques to study the effectiveness of artificial recharge structures have been developed.

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