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# STATUS OF ISOTOPE HYDROLOGY IN INDIAN ARID ZONE

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**ABSTRACT**

The complexity of arid Zone hydrology in the Indian context is outlined and some of the case histories dealing with the investigations on geochronology, groundwater movement, aquifer characteristics, surface/subsurface water inter-relationships. effects of aridity on groundwater recharge, vertical recharge studies and a synthesis of environmental isotopic data are presented. Isotopic techniques could also be utilised to understand precise knowledge on the interconnection between different aquifers, development of salinity and role of palaeowaters in controlling the geohydrology of any region in general and arid zones in particular.

## INTRODUCTION

Environmental isotope hydrology and artificial isotope hydrology constitute a relatively a new discipline in geosciences. In the environmental part, stable and naturally occurring radioactive isotopes have been used to study isotope variations established in waters by natural processes. Levels of these isotopes cannot be controlled by man, but they can be studied and interpreted to solve some hydrological problems on the basis of the variations in nature. In artificial isotope hydrology, radioisotopes are injected into the soil/water system under investigation and the variation of the isotopic conceneration (as a function of time and/or space) is followed. Validity of the date provided by this techniqus is limited to a restricted area (around the point of injection) and subject to the conditions present at the moment of injection. However, measurements performed at a sufficient number of points and repeated at different times can provide a good description of the hydrological system investigated (IAEA, 1981).

The development of isotope hydrology has been reflected, at the international level, in symposia held by International Atomic Energy Agency (IAEA, 1962, 1967, 1974, 1978, 1983 and 1987). At the national level, its developments have been discussed in various scientific meetings of the Department of Atomic Energy, Physical Research Laboratory, Bhabha Atomic Research Centre (BARC) and National Geophysical Research Institute.

The hydrology of arid western Rajasthan is beset with many problems mainly due to the shortage of water and excessive water demand of the ever increasing

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population of man and animal. Due to erratic and very low rainfall and limited surface water resources, more than 60 per cent of the population depends on groundwater resources for their subsistence. As a result of increased exploitation of groundwater resources, the adverse effects observed are the lowering of static water level, reduction of well yields and increase in total soluble salt contents. Presently, the groundwater in about 65 per cent of the area in western Rajasthan has salinity of over 3200 ppm (Chatterjee and Vangani, 1984). With this background information, some case studies are presented to reflect the status of isotope hydrology of arid western Rajasthan.

## CASE STUDIES

### Geo-chronology : Groundwater Movement Studies

Gupta and Nijampurkar (1974) studied the movement of groundwater at Palana, Bhairwa, Ajasar, Chandan, Devicot, Neron and Undu in the districts of Bikaner, Jaisalmer and Barmer. Their studies on deep seated aquifers revealed the age of the water (at depths of about 150m) more than 4000 years. In the case of the lower most aquifer at Ajasar, the age was worked out to be 17, 595 $\pm$ 230 years. The groundwater velocities based on the age measurements were of the order of 1 to 6 m/year.

### Aquifer Characteristics

Bahadhur et al. (1974) used radiotracer ($^{82}Ba$, $^{131}I$, $^{51}Cr$ and $^{3}H$) for studying the transmission characteristics of quaternary sandy deposits in Sikar basin, Rajasthan. The point diiution technique was employed to determine the filtration velocity in the soil formations. After correcting for the radioactive decay, distortions to hydrodynafield caused by borehole construction and diffusion of the tracer, the filtration velocities varied from 0.01 to 2.3. x $10^{-5}$ cm/sec. The soil stratification observed by core analysis natural gamma and electrical logs was also confirmed by the variations in the observed filtration velocities. Coefficient of permeability evaluated at various horizons gave an average value of 1.99 m/d and the transmissivity value of 85 $m^2/d$ against the corresponding values of 2.62 m/d and 112 $m^2/d$ from pumping tests. In another experiment, using the two well technique, tracer activity distribution curve showed three peaks corresponding to effective porosity values of 3.2%, 8.4% and 10.9% against an average value of 6.1% obtained by Boulton method (Fraczek and Bahadhur, 1974).

### Groundwater velocity at Nuclear Explosion site

Bhandari et al. (1978) used single point dilution method to estimate groundwater velocity in deep seated aquifers near the Pokaran (Jaisalmer district) nuclear test site. They used tritum injected by BARC in March, 1975 in a bore hole 225 m deep below ground surface near the test site. The tritium activity of 7 Ci/ml was detected in the well in May, 1975 which depleted by factors of 70 after about a year and futher by a factor of 2.5 in the following year. Based on these observations they found that the underground water movement in Lathi Basin is extremely slow (around 0.5 m/year). No radionucleides (expected to be produced in the explosion by fission or activation reactions) were detected in groundwater samples collected from the area.

### Surface/Subsurface Water Inter-relationships

Variations in the environment stable isotopes of water (measured as $\partial$ D and $\partial$ $^{18}O$) were used to study the surface and groundwater inter-relationship in Jawai reservoir region (Krishnamurthy and Rao, 1974). The reservoir did influence the groundwater regime and also there was a trend of decreasiug surface water inputs with increase in distance from the source.

### Effect of Aridity on Groundwater Recharge

Shallow groundwaters have a larger variation in $\partial$-values for $^{18}O$ and $^{2}H$ as compared to deeper groundwaters (Bahadhur, 1978). This character is also observed from recharge to discharge areas and is due to greater aridity as we move westwards (the ratio between potential evaporation and rainfall (450 mm) varies as 4 : 1 in the eastern Rajasthan to 8 : 1 in the western region where the normal annual rainfall reduces to 225 mm. Depth profiling of the groundwater as per sample (Table 1) shows that the deeper waters are enriched in $\partial$-values as compared to shallower waters. This is contrary to normal observations in other parts of the world where deeper water in arid regions are depleted in heavier isotopic content (recharge of pleistocene origin) (IAEA, 1983). There could be two possibilities to explain this; the lateral recharge from far off distances or the origin of the water is connected with changes in climate. Further, the $^{32}Si$ and $^{14}C$ dating (IAEA, 1968) for the groundwater from Palana, Jodhawas and Sayla indicate (Table 2) that these waters may be more than 2000 years old. This view is strengthened further from the fact that the Thar desert had been a centre of flourishing civilization in the past and the recharging events for groundwater have to be different from the present one due to changes in the climatic pattern.

### Radiotracer Injection for Vertical Recharge Studies

Estimations of natural recharge to the groundwater have been carried out by using tritium (Nair et al., 1978 and Sharma and Gupta, 1985) and tritium and cobalt-60 (Chandrasekharan, 1985). Nair et al. (1980) reported that under low moisture conditions, the tritium tracer may get into vapour phase during the day, they condense above the injection point during the night and thus complicate the interpretation of tracer profiles. Similar difficulties were faced by Sonntag et al. (1980) in the unsaturated zone of Dehna sand dune (Saudi Arabia) and elsewhere. To avoid this difficulty, the use of labelled potassium cobalt cyanide as a tracer was used and compared with the tritiated water. Results were quite comparable except for clay soils where the

Table 1. ∂D and ∂18 O values of groundwater samples from dug/tube wells in western Rajasthan

| S. No. | Location | Depth to water (m) | ∂D (%.) | ∂18 O (%.) | d=∂D − 8∂18 O |
|---|---|---|---|---|---|
| 1. | Sayla | 15 | —55.4 | —7.3 | 2.6 |
| 2. | Posana | 20 | —50.4 | —7.0 | 5.6 |
| 3. | Anandpura | 20 | —54.6 | — | — |
| 4. | Siwana A | 22 | —34 1 | —6.3 | 17.0 |
| 5. | Siwana | 22 | —40.5 | —5.7 | 5.2 |
| 6. | Kusip | 25 | —48 3 | —7.6 | 12,7 |
| 7. | Siwana | 24 | —46.3 | —6.4 | 5.0 |
| 8. | Siwana | 25 | —43.4 | —6.7 | 10.1 |
| 9. | Siwana | 27 | —41,4 | —6.2 | 8.1 |
| 10. | Devandi | 27 | —41.4 | —7.3 | 16.9 |
| 11. | Mawri | 28 | —43.2 | —6.2 | 6.2 |
| 12. | Kusip | 30 | —41.0 | —6.1 | 7.7 |
| 13. | Siwana | 30 | —36.7 | — 6.6 | 8.0 |
| 14. | Mawri | 30 | —32.6 | — 6.3 | 18.0 |
| 15. | Venkidari (DW) | 30 | —51.9 | —7.2 | 5.7 |
| 16. | Siwana | 33 | —36.8 | —6 8 | 17.3 |
| 17. | Jhunjunu | 40 | —54.6 | — | — |
| 18. | Anandpura (TW) | 40 | —54.6 | — | — |
| 19. | Valora (DW) | 43 | —53.2 | —7.1 | 3.6 |
| 20. | Bautra | 50 | —48 2 | — | — |
| 21. | Anandpura (TW) | 58 | —48.2 | — | — |
| 22. | Jhunjhunu (TW) | 60 | —48 6 | — | — |
| 23. | Jhunjhunu (TW) | 70 | —48.2 | — | — |
| 24. | Phagotra | 150 | —50.2 | —6.7 | 3.4 |
| 25. | Sayla | 175 | —42.2 | — 6.4 | 10.6 |
| 26. | Jodhawas | 266 | —35 3 | —5 1 | 5.5 |

TW — Tube well, DW — Dug well

Table 2. $^{14}C$, $^{32}Si$ Age of water, western Rajasthan

| S. No. | Location | Depth to water (m) | Uncorrected age (years) $^{14}C$ | Uncorrected age (years) $^{32}Si$ |
|---|---|---|---|---|
| 1. | *Palana (TW) | 168 | 5000 | 2000 |
| 2. | *Palana (DW) | 66 | 5000 | 2000±1000 |
| 3. | Jodhawas (TW | 266 | 17,858±800 | — |
| 4. | **Sayla (TW) | 175 | 2,830±200 | — |

* From IAEA, 1968 ** Artesian in nature.

tritium moved faster due to anion exclusion. Sharma and Gupta (1985) in their experiments indicated that even in a very low rainfall region, the fractional groundwater recharge could be substantial (7 to 15% of the rainfall).

Central Arid Zone Research Institute (CAZRI), Jodhpur, Defence Laboratory, Jodhpur and BARC, Bombay conducted co-ordinated experiments to estinate the groundwater recharge using tritium and cobalt-60 tracer in different areas of western Rajasthan (Table 3).

Table 3. Details of radiotracer injection, sampling and results in western Rajasthan

| Location | Depth of injection (cm) | Total Activity($\mu$Ci) $^{60}$Co | Total Activity($\mu$Ci) $^{3}$H | Displacement (cm) of the tracer after last sampling $^{60}$Co | Displacement (cm) of the tracer after last sampling $^{3}$H | Mean Moisture content (%) | Bulk density | Mean fractional recharge (%) |
|---|---|---|---|---|---|---|---|---|
| Siwana | 60 | 400 | 100 | 0 | 10 | 7.8 | 1.38 | 0.8 |
| Raital | 60 | 200 | 100 | Disturbed | 10 | 5.8 | 1.31 | 1.9 |
| Bhadrajun | 70 | 100 | 100 | 10 | 0 | 26.0 | 1.32 | 1 2 |
| Jodhpur | 70 | 320 | 100 | 38 | 35 | 13.0 | 1.52 | 13.0 |

Source : Chandrasekharan et al., 1988

**Synthesis of Environmental Isotopic Data**

The $\partial$D and $\partial^{18}$o values for precipitation were – 14.0‰ and – 2.25‰, respectively (Chandrasekharan, 1985) and the corresponding values of well water samples at different locations ranged from - 55.4‰ to - 32.6‰ and from –7.6‰ to –5.1‰ (Table 1). The $\partial$ D – $\partial$ $^{18}$0 relationship for the groundwater samples is $\partial D = 6.95 \partial ^{18}o - 1.94$ whose slope of 6.95 is closer to the slope of global precipitation line ($\partial D=8 \partial ^{18}o + 10$ ). The analyses of WMO-IAEA data of the region revealed that the summer monsoon precipitation was depleted more than the winter rain, the process of depletion continued with the progress of monsoon season and there was a larger variability in isotopic contents for Indian arid regions as compared to other arid regions of the world. The absence of environmental tritium in groundwater indicates that the present day local rainfall does not rdirectly echarge the groundwater in western Rajasthan and the waters are of pre-explosion origin. The $\partial$ values of well water samples at different depths do not follow any definite pattern. This may be due to their different origins and also poor intermixing at various depths.

The low $\partial$ values of well water samples (Table 1) and the corresponding values of precipitation in a relatively more humid area ( $\partial$ D = –51.2‰ and $\partial$ $^{18}$o = –7.65‰) are very nearly comparable indicating that these waters were of rainfall occurred at a time when that Thar desert was under a more humid and cooler period than at present. The stable isotopic composition shows that the shallow and deeper aquifers appear to be interconnected on a regional basis. The d-index ( $d = \partial D - 8 \partial ^{18}o$) varied from 2.6‰ to 17.96‰ averaging to 8.9‰ being close to 10 of the global precipitation line. Investigations by the BARC indicate that the deep wells could be recharged remotely through distant outcrops or recharged during a cooler period than the present. Sometimes recharge also occurs from local intense floods