ACTION RESEARCH ON TRACING ENVIRONMENTAL ISOTOPES IN ASSESSING GROUND WATER RECHARGE AUGMENTED FROM REHABILITATED MINOR IRRIGATION TANK CASCADE SYSTEMS IN GUNDAR BASIN, SOUTH INDIA

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ABSTRACT

Key Words: Tanks, Wells, Deutrerium, Oxygen-18 , radon, Recharge

Environmental isotopes may be defined as those isotopes, both stable as well as radioactive, which occur in the environment in varying amounts and over which the investigator has no direct control. The environmental isotopes most commonly used as tracers in hydrology are the deuterium, oxygen-18 and tritium (isotopes of the water molecule) carbon-13, carbon-14. nitrogen-15, and sulphur –34 (isotopes of dissolved solutes in water). Of these deuterium, oxygen-18, carbon-13, nitrogen-15 and sulphur-34 are the stable and the remaining are the radioactive.

The scientist team from Isotope technology Application Division of Bhabha Atomic Research Station has been involved with DHAN Vayalagam (Tank) Foundation in an action research programme by tracing three environmental isotopes namely oxygen-18, Deutrium and Radon from the water samples collected from rain and rehabilitated minor irrigation tanks at Tirumal cascade in Therkkar sub-basin of Gundar River basin during 2011-12. The water samples have been collected from rainwater, upstream observation well and all downstream wells during pre North East Monsoon, During North East Monsoon and post North East monsoon in the catchment and command area of Tirumal tank cascade. The paper would cover the findings of

[1] Conference speaker

rehabilitated tanks and their influence in recharging the ground water of downstream wells in the year of study. The results reveal the rehabilitated tanks play critical role in recharging the ground water and the recharge is influenced by the hydro-geomorphology, slope, soil type etc.

Environment Isotopes and their application in hydrology assessment

Isotopes have many applications in hydrological investigations as well as assessments and provide important information for the better management of water resources. Isotopes also help in understanding various hydrological processes. "Environmental isotopes" such as deuterium, oxygen-18, carbon-13, nitrogen-15 and sulphur-34 are commonly used in the developed countries by meteorologists, hydrologists, and hydrogeologists in the study of water resources like quantity, quality and period[i].

Useful stable isotope tracers and information they provide for water quality and environment

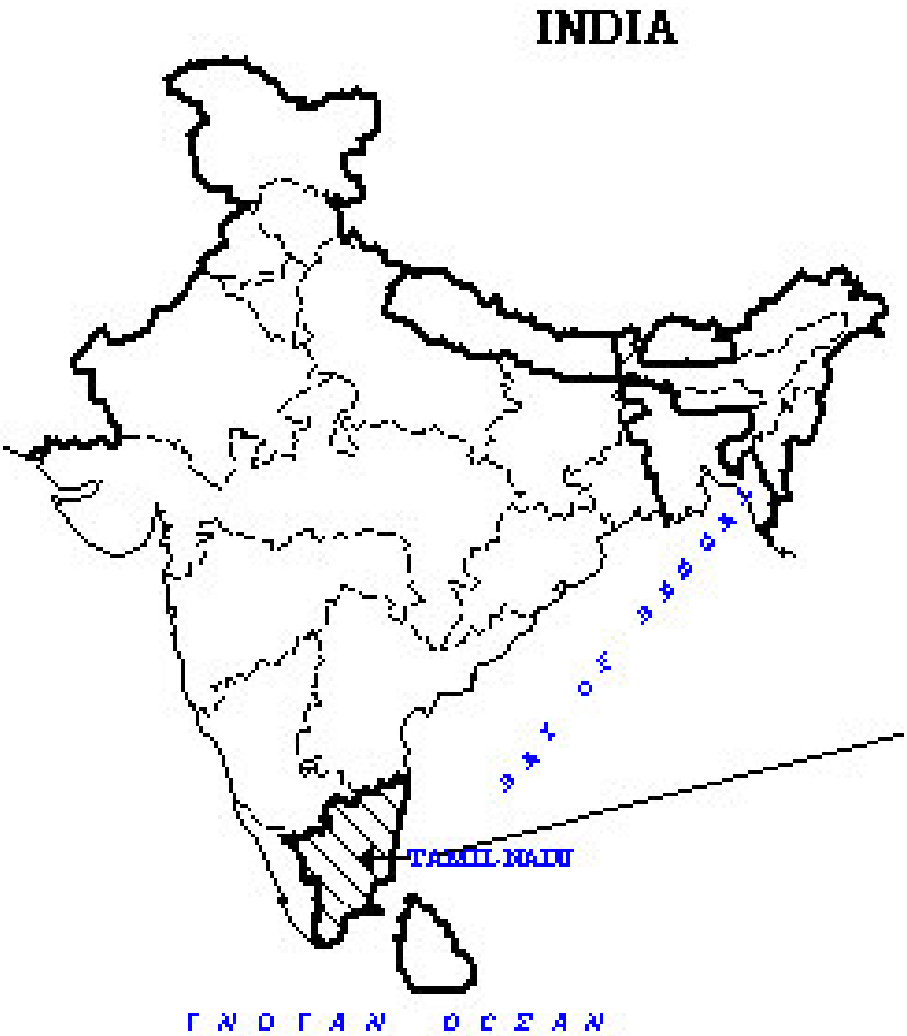
□^{18}O and □^{2}H of water	:	Ideal conservative tracer of water sources and mixing; useful for quantifying flow contributions from different tributaries and groundwater; sensitive indicator of evaporation
□^{18}O and □^{15}N of NO_3	:	Quantify NO_3 from different sources (fertilizer, wastewater, wetlands, atmospheric deposition, etc.); role in the production of algae and degree of recycling; evidence for denitrification, assimilation, and nitrification
□^{15}N, □ ^{13}C and □ ^{34}S of Particulate organic matter	:	Information on sources of POM; information about the source of the C, N, and S – and the biogeochemical reactions that cycle the elements – even after incorporation into algal biomass; quantify algal vs terrestrial contributions to biomass
□^{15}N, □ ^{13}C and □ ^{34}S of Dissolved organic matter	:	Information on sources of DOM; information about source of C, N, and S – and biogeochemical reactions that cycle the elements – even after incorporation into biomass; quantify algal vs terrestrial contributions to biomass; evidence for degradation of organic matter
□^{13}C of Dissolved Inorg. Carbon	:	Information on sources of DIC, evidence for in situ algal productivity, evidence for degradation of organic matter, degree of gas exchange with atmosphere, nitrification
□^{18}O of Dissolved Oxygen	:	Information about the ratio of productivity to respiration in the water column, source of the O_2, degree of gas exchange with atmosphere, biological oxygen demand (BOD) mechanism
□^{34}S and □^{18}O of SO_4	:	Quantify sulfate from different sources (soil, wastewater, wetlands, atmosphere, etc.), source of algae, and extent recycling
□^{18}O of PO_4	:	Quantify phosphate from different sources; information about the extent of algal production, recycling of material within the river reach, and P limitation

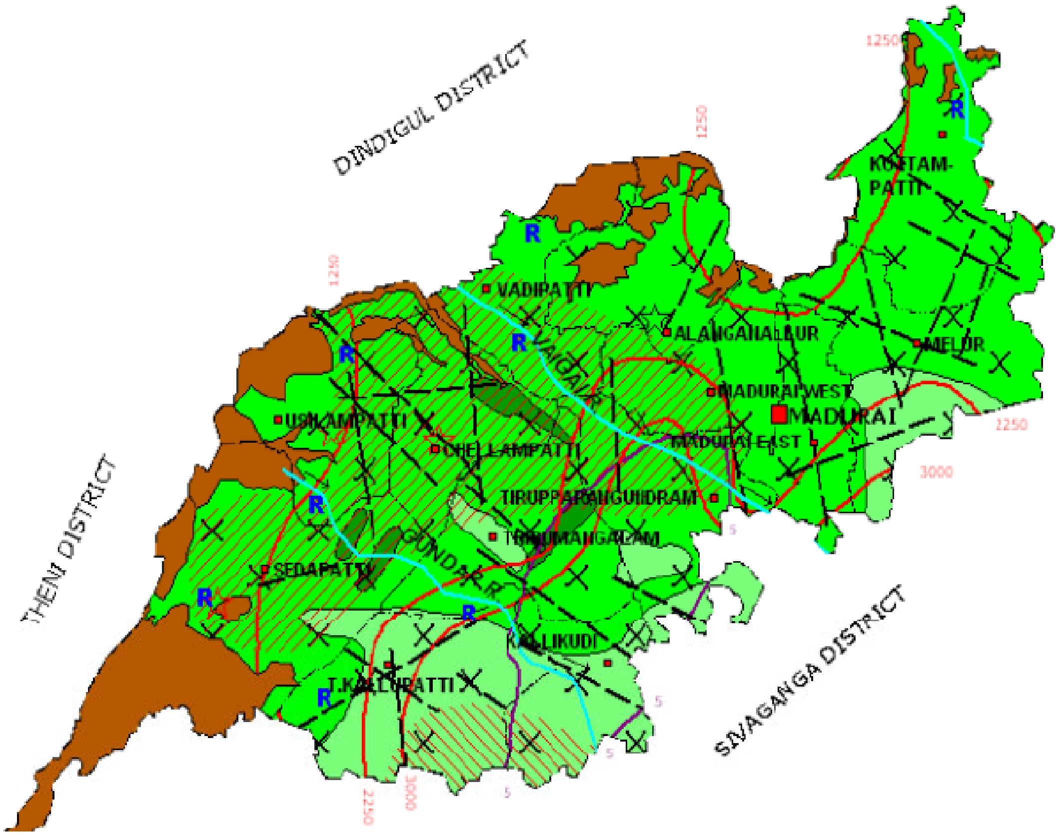
□^{15}N, □^{13}C, □^{34}S, □^{2}H and □^{18}O of Biota (algae, invertebrates, fish) :	Information on geographic origin of biota; information about the source of the C, N, and S – and the biogeochemical reactions that cycle the elements – even after incorporation into biomass; quantify algal vs terrestrial contributions to biomass; trophic structure; food chain base

Source: *"Isotope Hydrology as tool for water resources managers – A brief note"*
U.SaravanaKumar, Head Isotope Technology division, Bhaba Atomic Research Station, Mumbai

Action Research Project Area:

At the request of DHAN Vayalagam (Tank) Foundation, Madurai, an isotope hydrological investigation has been initiated at Tirumal Village with the technical support and collaboration of Isotope hydrology division of BARC, Mumbai in Therkkar sub-basin of Gundar river basin during 2011-12 Post Monsoon season onwards and studying the ground water recharge profiles of Urappareddy tank cascade in Thirumal. The objective of the study is to demarcate the zone of influence and to quantify the groundwater recharge from Urappareddi cascade of tanks. The project area is given in the figures given below.





Action Research Project Components:

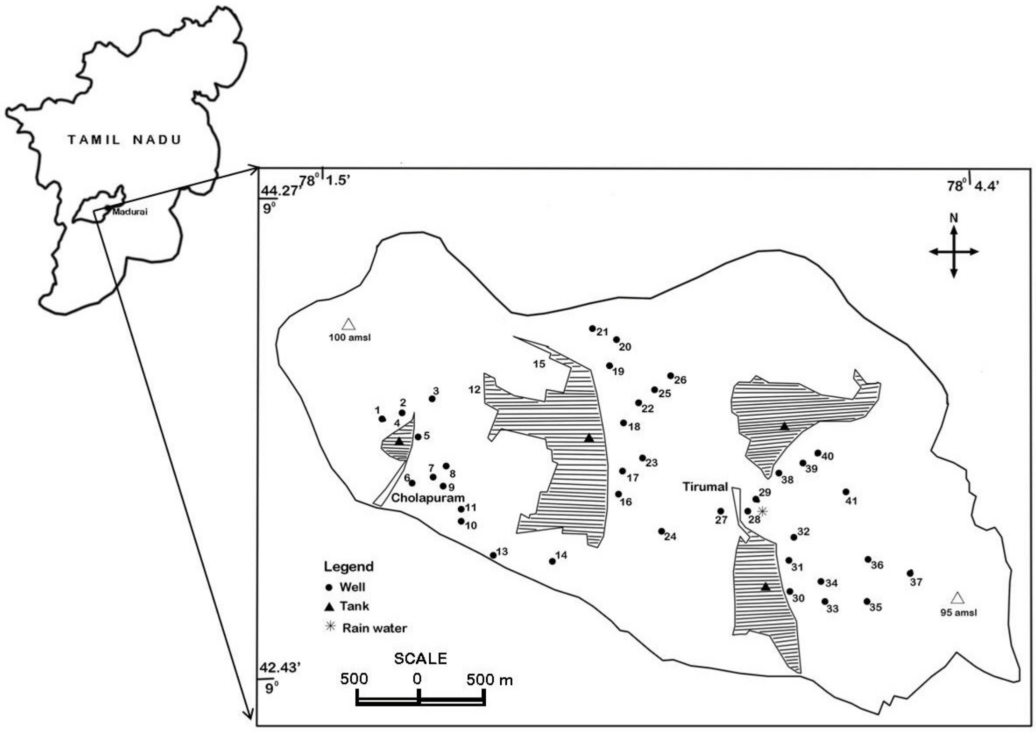
Rainwater Sample Collection: To trace environmental isotopes ^{2}H and ^{18}O, rain water sampling is the pre-requisite. In the ground water recharge study due to rehabilitation of tanks in the down stream area, a rain gauge has been installed on the terrace of a building at Tirumal village of T.Kallikudi block in Madurai district. The rainfall collected for particular period month wise, has been stored in a container and missed well. From the rainwater gathered from the raingauge, 50 ml water sample in narrow mouth bottle made out of high-density polyethelene (HDPE) or polypropylene (PP) bottles has been gathered. There is no need of any preservatives or filtration.

Surface water sample from irrigation tanks of Tiurmal cascade collection for ^{2}H, ^{18}O and ^{3}H :

In Tirumal tank cascade located at T.Kallikudi block covers four Minor irrigation tanks. These tanks fall in Therkkar sub-basin of Gundar River basin in Madurai district. DHAN Foundation has promoted social capital to rehabilitate these four tanks with Corporate Social Responsibility Funding from Hindustan Unilever Foundation, Mumbai. The renovation works have been completed in the Financial years 2010-11 and 2011-12 respectively.

Having come across the isotope tracing method for assessing the ground water recharge from irrigation tanks and their impact, DHAN Foundation has approached and involved Isotope Hydrology Division of Bhaba atomic research centre, Mumbai. Hydrology scientists with isotope application techniques headed by Dr.U.Saravana Kumar, Dr.Noble Jacob, associate scientist visited Thirumal tank cascade sites. The project team from DHAN Foundation also involved in the exercise and understanding of sample collection for tracing Deutrium and isotopes in the surface water bodies namely tanks.

In general, surface water collection poses few problems. Field measurements of physico-chemical parameters like temperature, pH, alkalinity, dissolved oxygen, salinity/conductivity have been measured using the digital probes. To inhibit the biological activity sodium azide or mercuric chloride in very minor quantities may be necessary. The water sampling in ponds, lakes, reservoirs can be done either from shallow or deeper depths, or from both. If the water body is shallow, the water samples are collected from a desired location below the water surface to avoid the effect of evaporation or at the outlet, where representative sample could be obtained, directly by dipping the sample bottle into the water body. In case of sampling from deeper water bodies, depth-water samplers or suction pumps are used. In such multilevel sampling physico-chemical parameters should be measured at every sampling point to obtain variation along the water column. In project cascade, the wells sample collected and the details is given in the following figure.[ii]



Groundwater Sampling for ^{2}H, ^{18}O and ^{3}H

Groundwater samples can be collected from hand pumps, private and government tube wells, piezometers, open wells/dug wells etc. However, it is necessary to ensure that a sample represents in situ groundwater without any contamination, evaporation, or effect of exchange with the atmosphere. Further, groundwater quality and isotopic composition may vary with depth and location. Therefore, the best way to collect the representative groundwater samples is to first collect the hydrogeological data of the study area. This helps to select sampling points and depth of sampling in different aquifers. Periodic sampling in wet and dry seasons may be necessary to understand spatial and temporal variations.

When the groundwater samples are to be collected from shallow aquifers, hand-pumped wells and shallow tube wells can be used after purging the standing water column for a few minutes. Shallow domestic wells or dug wells are found in large numbers in many of the countries. These wells are regularly used for irrigation and drinking water supplies and mostly represent shallow aquifers. But these are open and large in diameter; the groundwater in such wells is often subjected to evaporation and therefore it is not suitable for sampling. Such samples should be avoided if a nearby shallow hand-pumped well or tube well is available. However, if there is no other source, water samples can be collected from such wells after continuous pumping for various isotopic analyses.

Sampling groundwater for ^{2}H, ^{18}O and ^{3}H is simple and straightforward. Only 10 mL sample is required for ^{2}H and ^{18}O, but to be on safer side and for repeated measurements, 50 mL sample should be collected in HDPE/PP/Glass bottles. For low level tritium measurements using electrolytic enrichment followed by liquid scintillation counting, samples should be collected in similar bottles of 500 mL capacity. Fill the bottles completely and ensure airtight seal. If the samples are to be stored for longer period, they should be sealed with wax and stored at low temperature (4°C). No other treatment such as filtration and preservation is required. On site measurements like sample temperature, pH, conductivity, dissolved oxygen, alkalinity, etc. along with all other relevant site information should be recorded. Caution should be exercised to crosscheck the information on labels and that recorded in the field notebook.

Table-1: Summary of sampling for ^{2}H, ^{18}O and ^{3}H in precipitation, surface water, vadose water, and groundwater

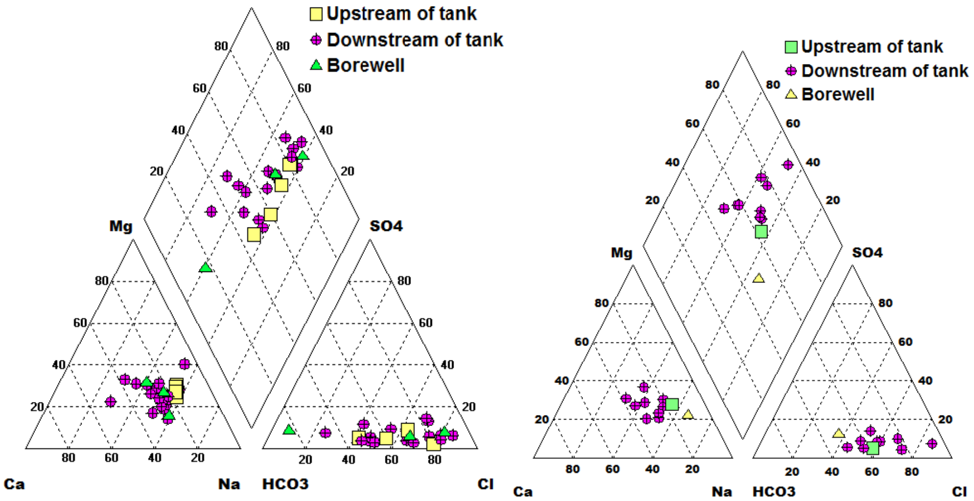
Isotope	Method of Analysis	Analytical precision	Sample amount	Preservation and sampling bottle	Storage
^{18}O	IRMS	± 0.1 ‰	10 mL	no preservative, plastic bottle	>1 year
^{2}H	IRMS	± 1 ‰	10 mL	no preservative, plastic bottle	>1 year
	Enrichment + LSC	± 0.8 TU	500 mL	no preservative, plastic bottle	Decay:
^{3}H	Propane synthesis	± 0.1 TU	1000 mL	no preservative, glass bottle	$T_{1/2}$=12.3
	^{3}He in-growth + MS	± 0.1 TU	50 mL	no preservative, glass bottle	

Water sampling

October 2012

Hydrochemical data[iii]

The monsoon during 2012-13 was failure. Even then, the urappareddy cascade tanks received water because of rehabilitation of supply channels, repairs to surplus weirs and new construction of sluice structures. The samples collected from the project site was sent to high profile water quality testing laboraratory to measure the hydrochemical data and so on. Results indicate that the wells away from the irrigation tanks are brackish in nature. Most of the well samples are contaminated with nitrate

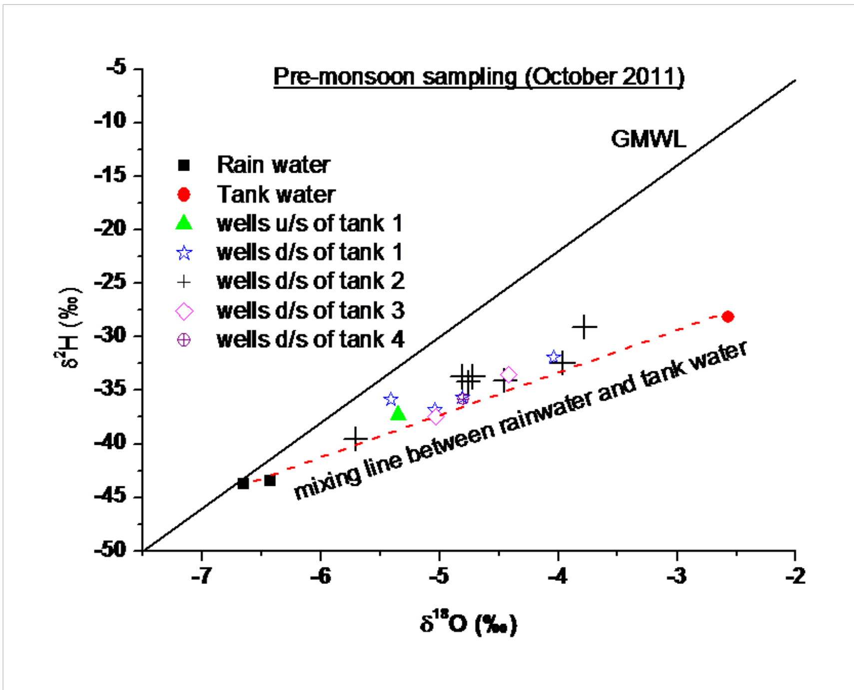


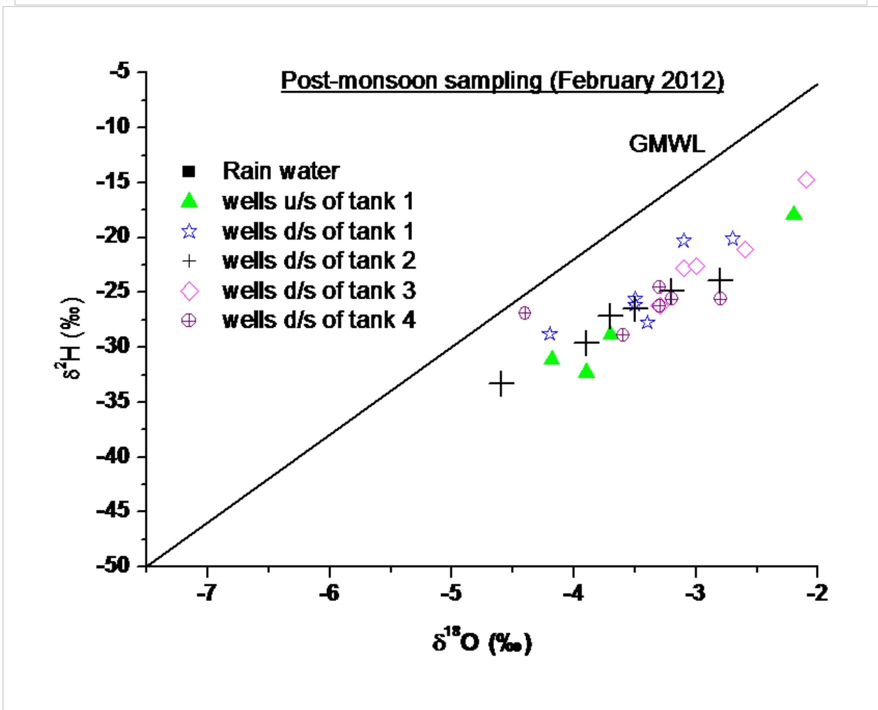
Piper's trilinear diagram for (pre & post monsoon) groundwater samples

- Upstream (away from the influence) of irrigation tanks: Na-Mg-Cl-HCO_3 type.
- Downstream (close to the influence) of irrigation tanks: Na-Ca-Mg-Cl-HCO_3
- Bore well samples: Na-Mg-Ca- Cl-HCO_3 type.
- Brackish samples: Na-Ca-Mg-Cl type.

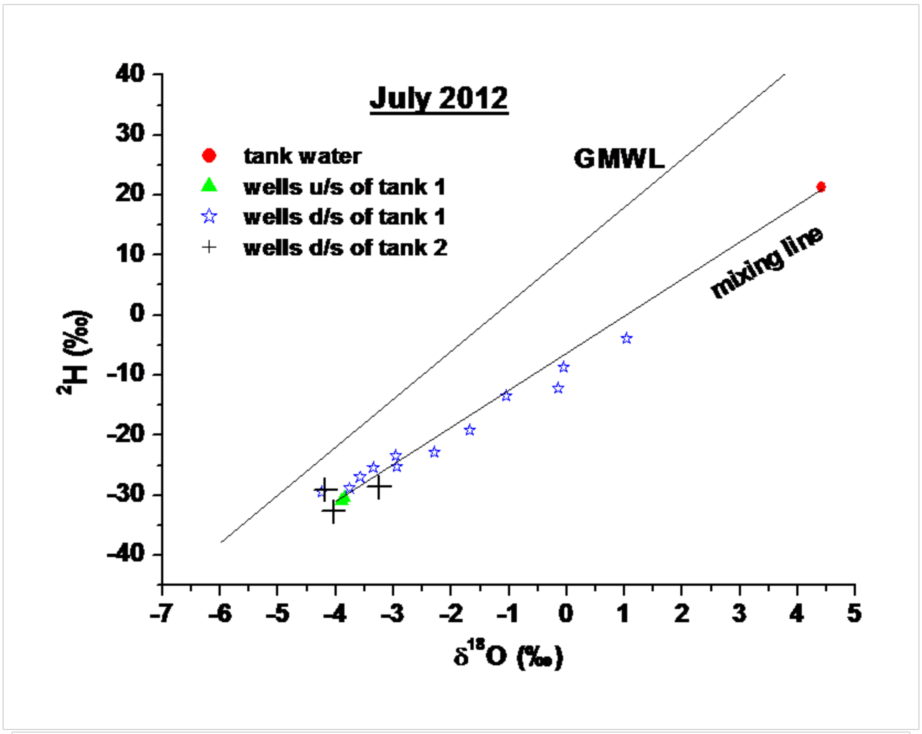
Stable isotope data (δ^2H & $\delta^{18}O$)

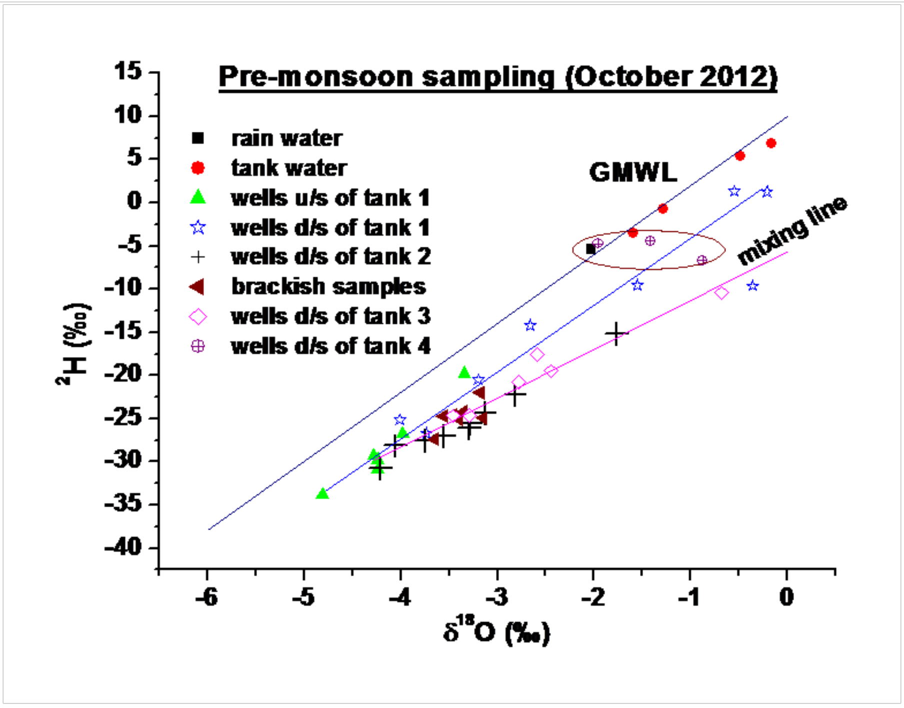
About 20 Nos. of pre-monsoon and 35 Nos. of post monsoon groundwater samples were collected and analysed for δ^2H & $\delta^{18}O$





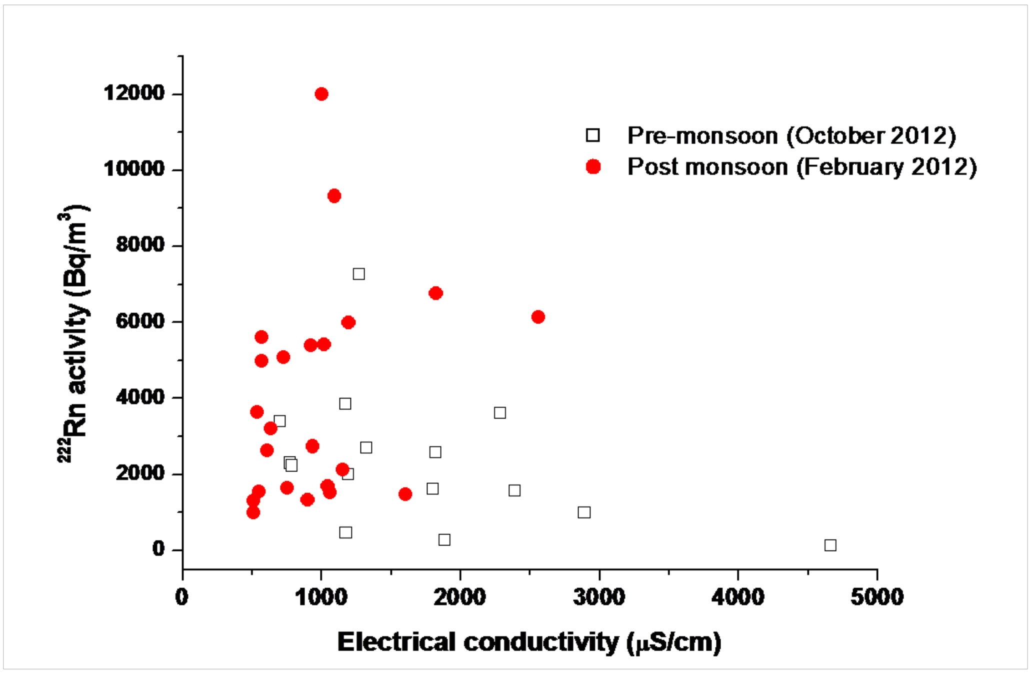
Preliminary results show that the d/s well water samples lies in a mixing line between the tank water and the rainwater in the $\delta^{18}O$ - $\delta^{2}H$ plot, indicating groundwater recharge from the irrigation tanks



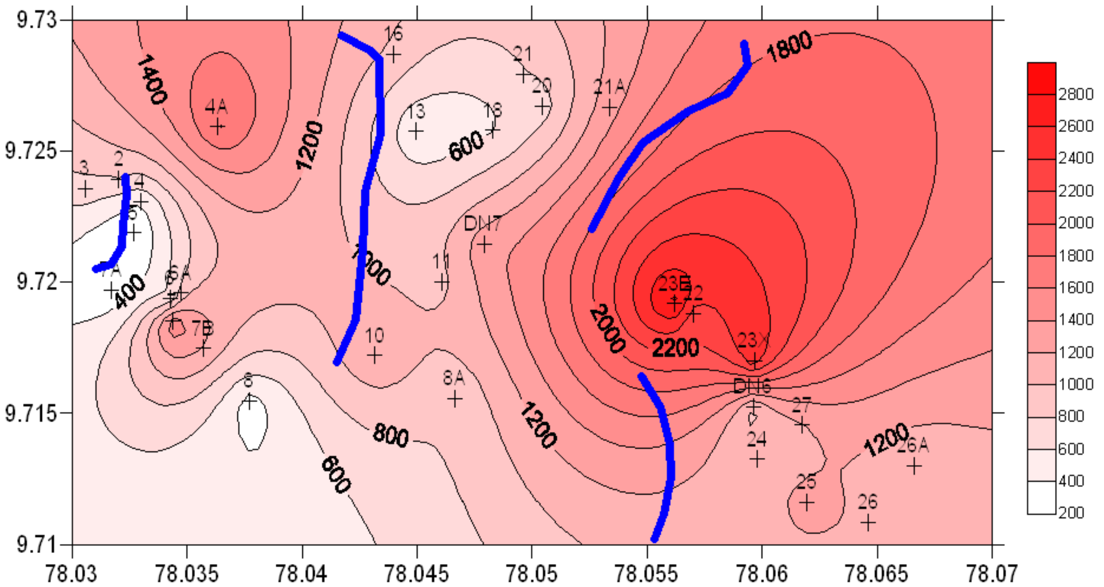


Radon data

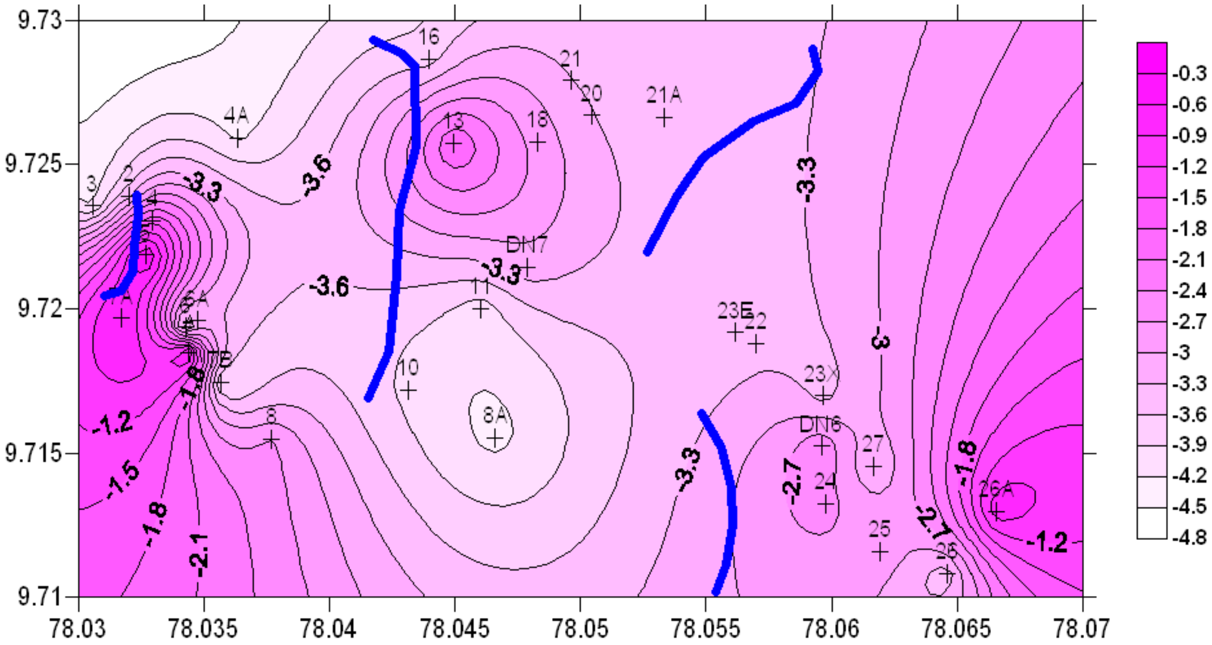
About 20 Nos. of pre-monsoon and 35 Nos. of post monsoon groundwater samples were collected and analysed for radon (^{222}Rn)



Higher ^{222}Rn activities and lower electrical conductivities are observed during post monsoon samples, indicating groundwater recharge through the weathered zone.



Spatial distribution of electrical conductivity (μS/cm) in Oct'12



Spatial distribution of d^{18}O (‰) in Oct'12

Longitudinal spread
Tank 1 - 0.5 km
Tank 2 - 0.8 km
Tank 3 – 0.9 km
Tank 4 – 1 km

Findings

- Hydrochemical results indicate that the wells away from the irrigation tanks are brackish in nature.
- Most of the well samples show nitrate pollution probably because of the excess use of fertilizers in this area.
- Stable isotope results indicate groundwater recharge from the irrigation tanks.
- Higher ^{222}Rn activities and lower electrical conductivities are observed in the post monsoon samples, indicating groundwater recharge through the weathered zone

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[i] Dr.U.Saravanakumar; Useful Isotope Information as hydrology tools for water managers
[ii] Dr.U.Saravanakumar; Sampling Methods for environmental Isotope tracing
[iii] The entire analysis is based on interim action research finding presentation made at BARC by Dr.Noble Jacob, Scientist, Isotope hydrology division