African Journal of Environmental Science and Technology Vol. 4(4), pp. 226-233, April 2010
Available online at http://www.academicjournals.org/AJEST
DOI: 10.5897/AJEST09.096
ISSN 1991-637X © 2010 Academic Journals

Full Length Research Paper

Environmental isotopes investigation in groundwater of Challaghatta valley, Bangalore: A case study

M. Jiban Singh[1*], Deljo Davis[1], R. K. Somashekar[1], K. L. Prakash[1] and K. Shivanna[2]

[1]Department of Environmental Science, Jnanabharathi, Bangalore University, Bangalore.
[2]Water Resources Development Section, Isotope Application Division, Bhabha Atomic Research Centre, Mumbai.

Accepted 17 February, 2010

Radiogenic isotopes (3H and 14C) and stable isotope (18O) together with TDS, EC and salinity of water were used to discriminate qualitative and quantitative groundwater age, probable recharge time, flow respectively in groundwater of Challaghatta valley, Bangalore. The variations between TDS and EC values of sewage, corporation water, bore and open wells with concomitant variations in salinity confirmed an immerse relationship with the depth of wells, Also, the source of recharge and contamination of groundwater as sewage. However, lighter δ18O bearing water more commonly occurred at higher elevations and heavier at lower elevations in the entire valley presenting a clear enrichment in δ18O probably due to evaporation and confirming major source of surface water as South - West monsoon. The groundwater samples in valley contained higher 3H except five samples (OW21, OW24, BW5, BW20 and BW24), suggesting recent recharge and categorized as modern age water. Further, from the results of 14C it is inferred that some groundwater samples in Challaghatta valley belongs to old water regime with pmC values ranging between 58 and 112.

Key words: Groundwater age, isotopes, recharge duration, salinity, sewage.

INTODUCTION

Bangalore, known, as the Silicon Valley of Asia, is one of the major class I cities in South India with a population of 8.1 million. It is a rapidly growing city with congregation of software and automobile industries. The increasing demand to meet the water requirements has been enormous. However, Bangalore harbors no perennial river, which resulted in the growth of many lakes, Arkavathi, Pinakini, and Vrishabhavathi Rivers acting as a source of groundwater recharge earlier.

Currently, following rapid urbanization and industrialization, these lakes have vanished and have been converted into residential, commercial localities as well as Arkavathi, Pinakini, and Vrishabhavathi streams are today part of open Sewerages network of the city. The long industrial history of Bangalore city results in complex patterns of pollution that impact on the underlying groundwater quality. The dominant industries are textile, cement, liquor, tobacco, gold, electronic, food and industrials metal manufacturing.

During the last two decades environmental isotope techniques have largely been used in the overall domain of water resources development and management (Fritz and Fontes, 1980). In fact, the application of these relatively new techniques has played an important role in solving the envisaged hydro-geological problems unsolved by conventional methods. To understand the relative significance of recharge time and processes, groundwater flow path, quality and quantity age are critical parameters. An accurate conceptualization is therefore a prerequisite for realistic simulation of a flow system. To better understand the flow system and translate this understanding to develop a groundwater model, data on radiogenic isotope viz. 3H and 14C, stable isotope 18O along with groundwater TDS, EC and salinity could be used.

MATERIALS AND METHODS

Seventeen open wells, 15 bore wells, 4 corporation water and 3 sewage samples were collected in polyethylene bottles after 10 min of initial pumping and transported to laboratory at 10°C to prevent any contamination pre acid and distilled water washed from the Challaghatta valley. The groundwater sources were within 70 to 500 m radius, proximity of open sewage system.

*Corresponding author. E-mail: researchermj@yahoo.com.

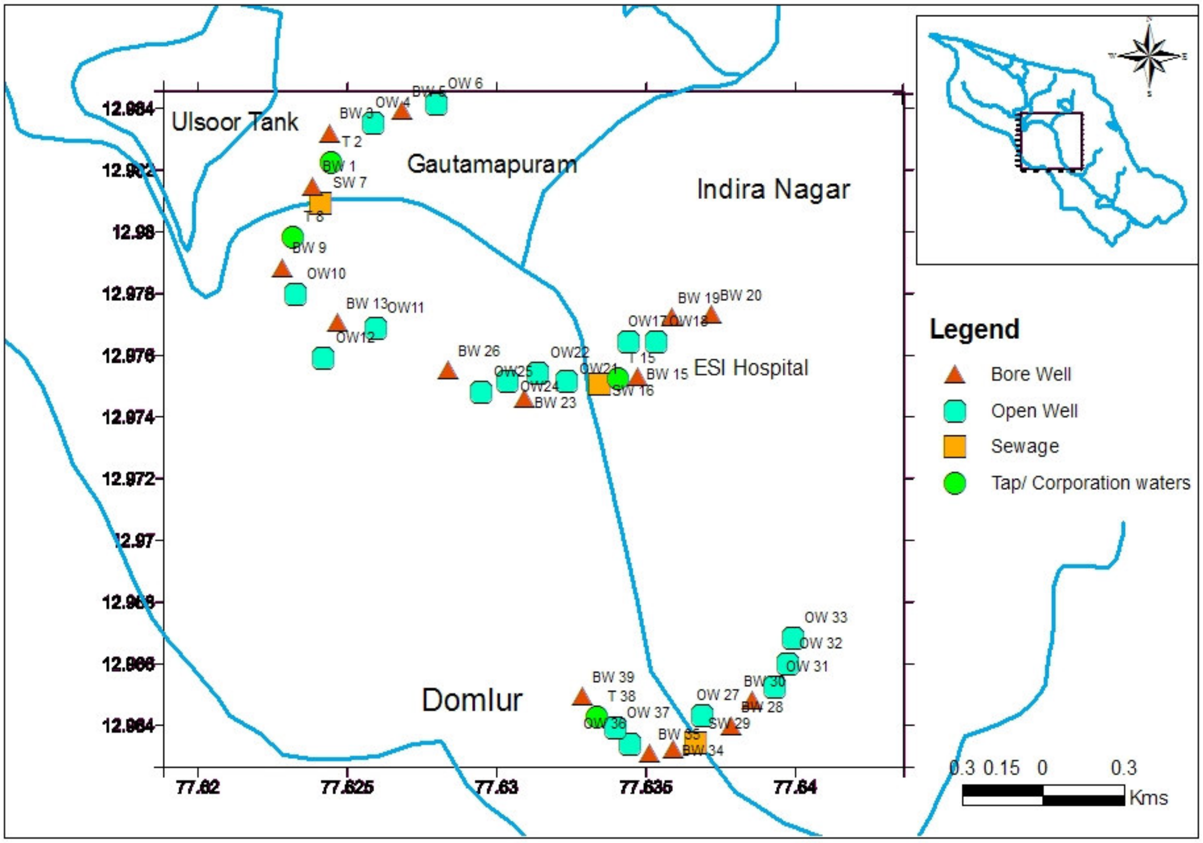

Figure 1. Sampling locations with sewerage network system of Challaghatta Valley, Bangalore.

The sample location was chosen in such a way that it represents either side of the represented both nearer and away from the sewage cannel (Figure 1). Also 12 rain water samples were collected during the first and second monsoon of 2008 for 18O and 3H measurement. After recording the 3H levels (< 4 TU), to determine the carbon isotopic composition, CaCO3 of groundwater was precipitated (OW21, OW24, BW5, BW20 and BW24), which holds the total carbon contained as dissolved component.

After sampling, TDS, EC were measured in the field using PE - 138 field Kit (APHA, 2005) and salinity of water was classified according to Handa (1969). Tritium, 14C and 18O analysis was done at the Tritium and Radiocarbon laboratory of Bhaba Atomic Research Centre (BARC), Mumbai, using liquid sentillation and mass spectrometric methods.

The drainage system

The granitic ridge running from NNE to SSE governs the drainage pattern of Bangalore North. Towards east, the drainage is made up network of canals generally flowing from west to east with storage tanks along the canals, ultimately feeding the South Pinakini River. In the west, the drainage pattern is composed of network of canals generally flowing from east to west with storage tanks, ultimately feeding the Arkavathi River. Also, the Bangalore South drain towards East, into the Pinakini basin and to the West into the Arkavathi basin. The Vrishabhavathi is the only minor river within the city marked with a series of tanks. A continuous chain of hills through which several rivulets join together and drain into the Arkavathi marks the western portion of Bangalore.

Geo – hydrological nature

Geologically the Western portion of Bangalore is composed of gneissic granites belonging to Precambrian age. The gneissic granites are exposed as a continuous chain of mounds raising 90-150 m above the ground on the western portion constituting the Bannerghatta groups of hills. Inclusions of quartz and pegmatite also occur here and there (Figure 2).

Hydro-geologically Western portion shows groundwater occurrence under water table in the weathered mantle of the granite gneisses and joints, cracks and crevices of basement rocks. Generally, the water table fluctuation in open and bore wells of Challaghatta valley are high around Domlur and Ulsoor Lake respectively, which are major recharge areas of groundwater. The depth of water table is dependent upon the rate of weathering and topographic factors. Chief source of groundwater is infiltration and recharge by rainwater. Considering the climatic water balance, soil characteristics account for nearly 70% allowing only 20% rainfall being added to groundwater pool. Percolation and recharges in the groundwater account for 10% discharge through wells.

RESULTS AND DISCUSSION

The average values of TDS and EC in bore and open well samples are 545 mg/l and 1089 µS/cm and 490 mg/l and 942 µS/cm respectively (Table 1). The corporation water is medium saline (good quality), 88.2 and 86.7% in open and bore wells samples along with sewage

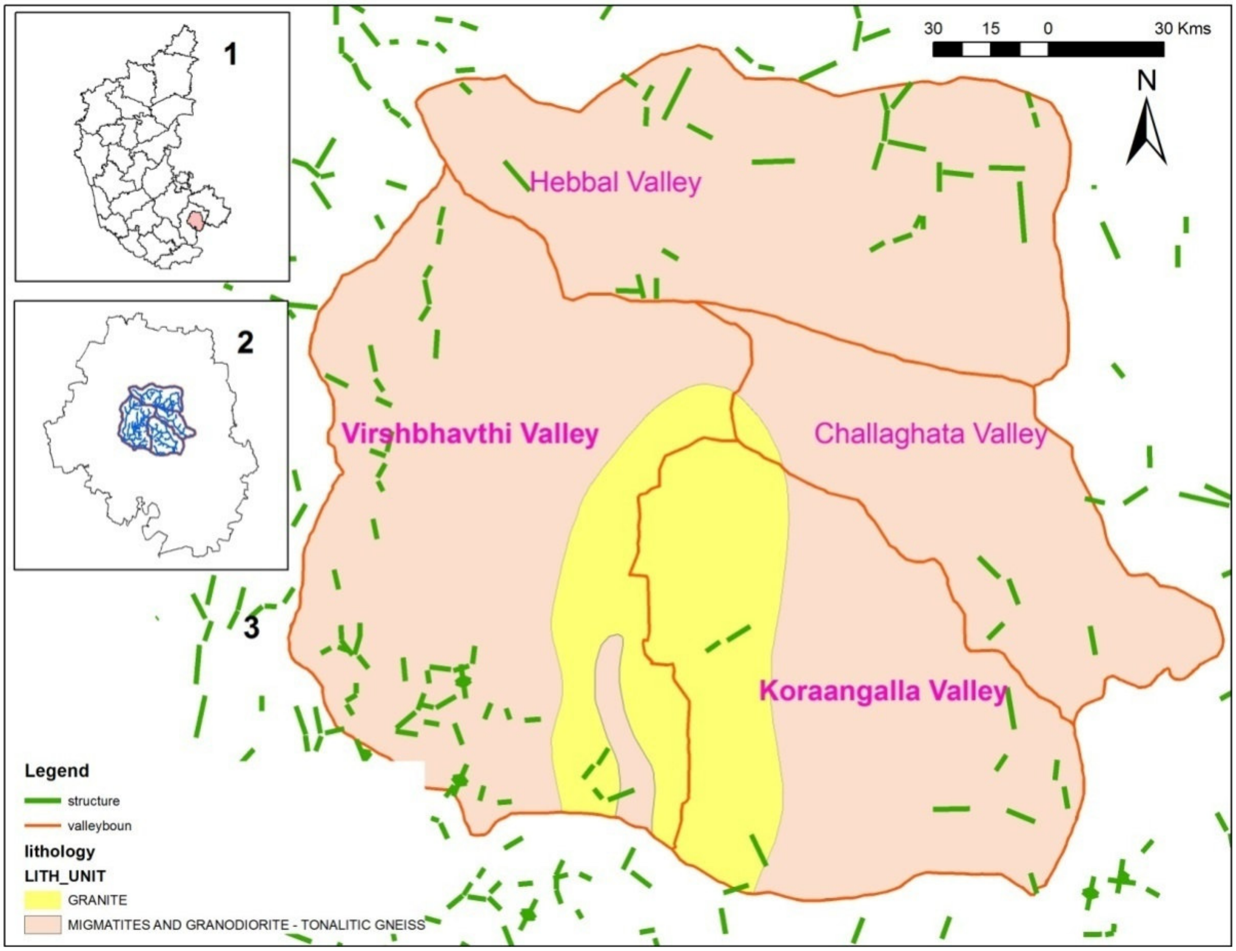

Figure 2. Geological background of Challaghatta with surrounding valleys.

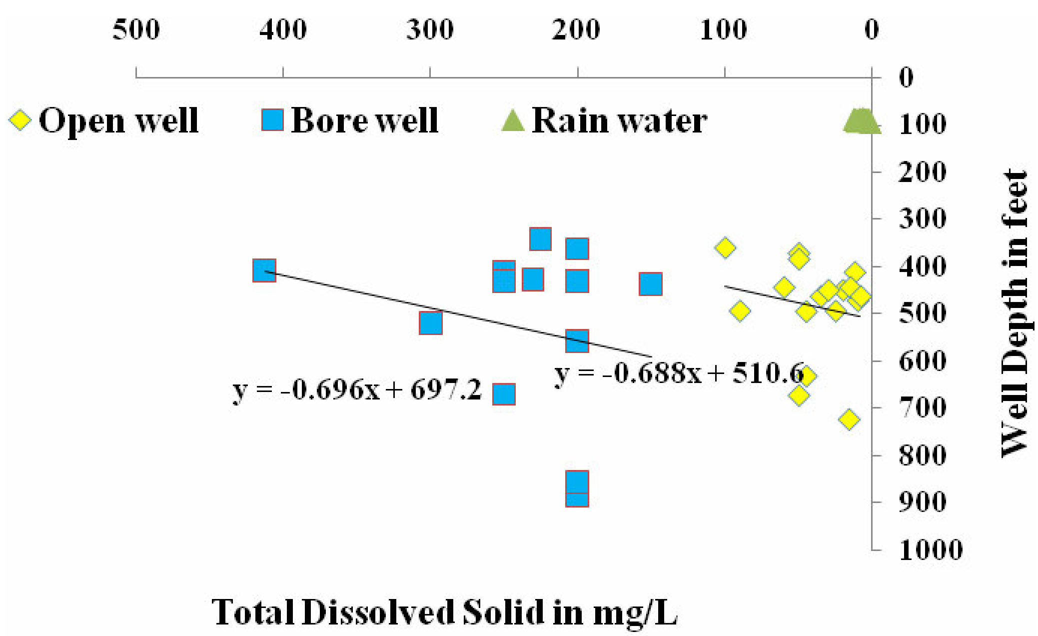

Figure 3. Plot of TDS versus open and bore wells depth showing increase in salinity at shallow aquifers and low salinity in rain water.

Table 1. Physico-chemical and environmental isotopes values in Challaghatta valley.

Sample ID	Location	Elevation (meter)	Depth (feet)	Distance S/W (meter)	TDS (mg/l)	EC (µS/cm)	$\delta^{18}O$ (%oSMOW)	^3H (TU)	^{14}C (pmC)
				Open well					
OW4	MV Garden	898	50	250	372	609	-2.4	8.2	Modern
OW6	Dobi cottage	906	50	550	673	1213	-3.0	6.3	Modern
OW10	RK Mutthu road	904	100	250	360	748	-2.5	6.8	Modern
OW11	RK Mutthu road	910	12	325	412	649	-3.0	6.0	Modern
OW12	RK Mutthu road	905	10	500	472	944	-2.8	6.7	Modern
OW17	Indiranagar	891	50	300	384	768	-2.3	8.2	Modern
OW18	Indiranagar	919	45	350	495	990	-3.0	5.2	Modern
OW21	Saraswathipuram	938	16	100	724	1452	-4.1	3.6	60
OW22	Appaiah garden	921	45	100	632	1264	-3.2	4.8	Modern
OW24	Appaiah garden	925	20	250	450	800	-3.5	3.6	58
OW25	Appaiah layout	873	35	400	463	926	0.0	10.3	Modern
OW27	Domlur 2nd stage	903	15	70	444	888	-2.4	6.8	Modern
OW31	Domlur 2nd stage	905	25	250	494	988	-2.8	6.6	Modern
OW32	Domlur 2nd stage	891	30	500	450	800	0.0	10.3	Modern
OW33	Domlur 2nd stage	904	8	500	463	926	-2.4	6.7	Modern
OW36	Airport road	905	60	250	444	888	-2.8	6.6	Modern
OW37	Domlur village	919	90	300	494	988	-3.0	5.2	Modern
				Bore well					
BW1	Gautamapuram	902	200	25	557	1114	-3.3	7.2	Modern
BW3	MV Garden	908	150	100	438	876	-3.4	5.0	Modern
BW5	MV Garden	936	225	500	342	684	-4.4	3.9	105
BW9	Lakshman road	865	413	100	410	820	-2.4	10.6	Modern
BW13	RK Mutthu road	909	250	500	412	824	-3.4	4.4	Modern
BW15	Indiranagar	924	200	100	868	1761	-3.6	4.2	Modern
BW19	Indiranagar	925	300	500	520	1025	-4.1	4.0	Modern
BW20	Indiranagar	953	200	500	430	860	-4.9	3.5	125
BW23	Saraswathipuram	997	250	150	431	862	-5.9	1.9	112
BW26	Jyothi palaya	881	200	500	432	835	-2.5	9.3	Modern
BW28	Domlur 2nd stage	891	250	60	671	1341	-2.6	7.6	Modern
BW30	Domlur 2nd stage	871	230	230	429	858	-2.4	10.5	Modern
BW34	Domlur bus stop	886	200	100	885	1769	-2.8	8.4	Modern
BW35	Prasanna	904	200	150	364	727	-3.3	5.4	Modern
BW39	Chapalamma temple	891	200	500	856	1711	-3.1	8.3	Modern

Table 1. Contd.

				Tap/Corporation				
T2	Tap water	901	40	205	412	-0.2	6.3	Modern
T8	Tap water	865	50	200	409	1.8	8.3	Modern
T14	Tap water	924	50	203	400	-0.3	5.7	Modern
T38	Tap water	919	350	210	400	-1.5	10.2	Modern
				Sewage				
S7	MV Garden	901		423	846	-2.5	12.9	Modern
S16	ESI Hospital	896		484	967	-2.0	4.8	Modern
S29	Domlur 2nd stage	874		864	1727	-2.5	16.6	Modern

exhibited high salinity (permissible quality). The depth of well samples is inversely proportional to salinity, confirming the source of recharge and contamination of groundwater as sewerage network (Figure 3). Also, higher TDS is accounted by the presence of HCO3, SO4, Cl, CaH, MgH, and Na respectively as recorded by Nawlakhe et al., (1995). The causes of higher TDS and EC are the combined effect and lithologic variations, industrial and domestic discharge into sewage system and the consequent contamination as reported by Chebotarebv (1985); Rambabu et al., (1986); Joseph (2001) and Mohapatra et al., (2001), concurred that slightly alkaline condition favor higher TDS in groundwater.

Oxygen - 18 (δ18O)

Variations in the stable-isotope signature of water in the catchment are caused mainly by natural variations in the isotopic composition of rainfall and through mixing with pre-existing water and the influence of evaporation. Rain water from the nearest global network of isotopes in precipitation (GNIP) site in Chihuahua, Mexico, with a mean δ18O value of -6.5%o SMOW with a range of -18.8 to -1.3%o SMOW for samples collected in June to December of 2005. The In rain water samples collected from the valley between June and December 2008, had a mean δ18O value of -3.75%o SMOW the a range of -12.63 to -1.82%o SMOW (Figure 4).

A comparison of δ18O range values of the open well (-4.1 to 0.0%o SMOW), bore well (-5.9 to -2.4%oSMOW), corporation (-1.5 to 1.8%o SMOW), and sewage (-2.5 to -2.0%o SMOW) with δ18O range values of rain water (-8.25 to -0.18%o SMOW), confirmed that South-West monsoon (June to August) accounts ~80% of total rainfall on the input signal (Figure 4). Also the groundwater from shallow quaternary aquifer has most probably originated from South – West monsoon precipitation.

The average trend in δ18O heavier values [Corporation (0.0%o SMOW) >Sewage (-2.3%o SMOW) >Open well (-2.5%o SMOW) >Bore well (-3.6%o SMOW)>Rain (-3.8%o SMOW)] suggest the possible concentration of δ18O in ground-water representing percolation during the runoff at rainy season besides infiltration from sewage and lakes. It also supports the view that the sewage act as a hydraulic move to ground flow. The high elevation areas like Appaiah garden, Saraswathipuram, Indiranagar and MV-garden showed depleted δ18O indicating strong South-West monsoon and high runoff. None the less remaining showed on areas increasing trend in δ18O suggesting low runoff (Figure 5).

Therefore, it is obvious that, groundwater δ18O values indicate a preferential trend in their spatial distribution. Lighter _ δ18O bearing water more commonly occurred at higher elevations and heavier at lower elevations in the entire basin presenting a clear enrichment in δ18O, due to evaporation from sewage and sewage mixed groundwater (Figure 5).

Tritium (^{3}H)

Relative dating of groundwater has been carried out via the analysis of tritium content. The bore well water from the valley had a mean tritium value of 6.3 TU ranging between 1.9 and 10.6 TU whereas; 0pen wells exhibited a mean tritium value of 6.6 TU and a range of 3.6 to 10.3 TU.

The corporation water mean tritium value was 7.7 TU while that of sewage is 11.1 TU and ranging between 4.8 and 16.6 TU (Table 1).

The apparent qualitative age of groundwater is

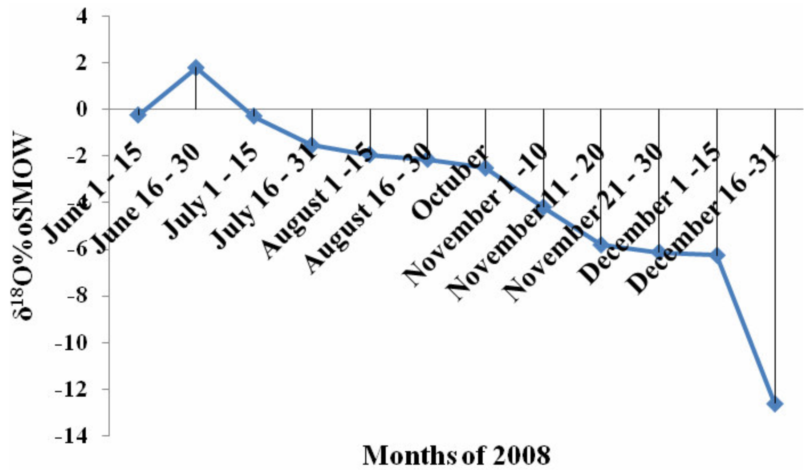

Figure 4. Fractionation of $\delta^{18}O$ %o SMOW of rain water in different months during 2008.

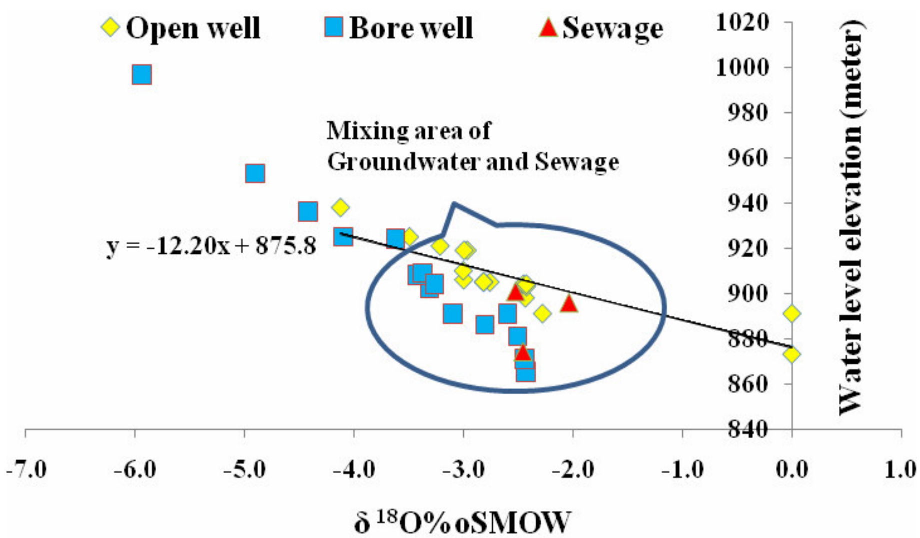

Figure 5. Plot of $\delta^{18}O$ vs. water level elevation of Sewage, open and bore well samples ($\delta^{18}O$ values become heavier at lower elevations).

considered to be the amount of time determined from an age - dating tracer that has elapsed from the time water lost contact with the atmosphere. Tritium is a short - lived radioactive isotope of hydrogen with a half-life of 12.32 years. Tritium is formed naturally as cosmic radiation interact with the upper atmosphere, and all precipitation that falls to Earth has small amounts of tritium. During the 1950s and early 1960s, global atmospheric testing of nuclear weapons raised the atmospheric concentrations of tritium hundreds of times above the normal background concentration (Plummer et al., 1993).

After the early 1960s, when the Nuclear Test Ban Treaty (NTBT) was signed and atmospheric testing of nuclear weapons ceased, tritium concentrations in the atmosphere decreased and are approaching natural levels. Tritium concentration alone generally cannot be used to quantitatively date groundwater, but can be used to qualitatively determine whether groundwater is modern (less than about 50 years in age) or pre - modern (older than about 50 years in age) (Clark et al., 1997; Zouari et al., 2003).

Modern age is further classified depending on 3H values where in values ranging from 1 to 4 TU could be attributed as mixture of recent water with old groundwater and groundwater having been subjected to radioactive decay. Recent water with activities between 4.1 and 18 TU and thermonuclear water with activities between 18.1 and more than 28 TU. In this present case 18.8% of the groundwater samples from the valley represent mixture, 81.2% recent with activities, as well as totally recent with

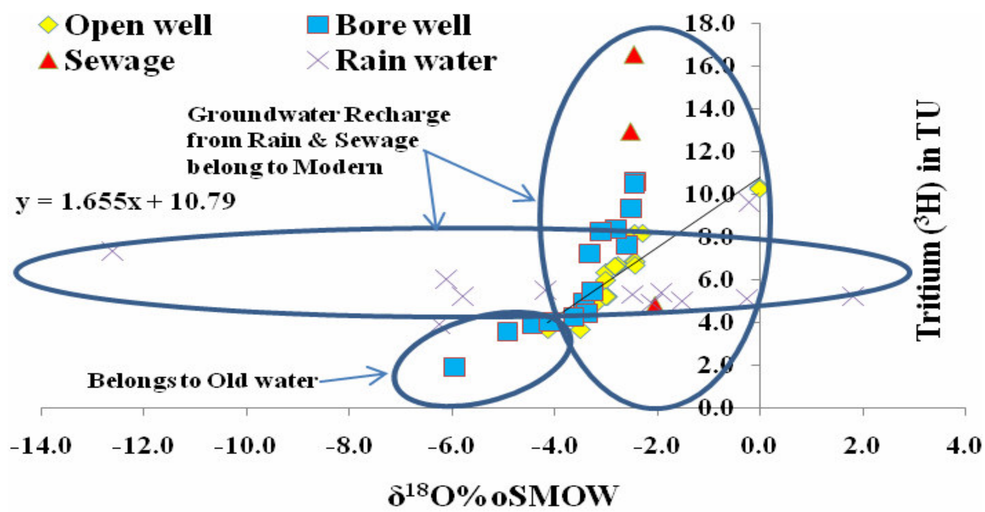

Figure 6. Plot of ^3H vs. δ18O%oSMOW of sewage, rain water, open and bore well samples.

activities as in sewage and corporation water (Table 1). Further modern groundwater generally is more susceptible to contamination than old because of many anthropogenic contaminants introduced during the 20th century (Plummer et al., 1999). Therefore the sites with depleted 3H values belong to old groundwater, and those with increase in 3H values represent recharge from rain and sewage (Figure 6). The spatial distribution of tritium in the present case indicates that it followed the same trend as 14C, with lower tritium at higher elevations and vice-versa in the entire valley The trend in tritium values [Sewage (11.1 TU) > Corporation (7.7 TU) >Open well (6.6 TU) >Bore well (6.3 TU) > Rain (4.5 TU)], suggest the possible contaminants of 3H in groundwater following recharge from sewage with, little contribution from precipitation. The `higher 3H in groundwater samples along the sewerage network again support the view that the sewage act as a hydraulic move to groundwater flow (Morteza et al., 2006).

Carbon - 14 (^{14}C)

Since 1952, as a result of testing thermonuclear devices we got another isotope added to the atmosphere that is Carbon -14, like tritium. Corresponding to 31.56 dpm/g of carbon, before 1952 14C the about 100 pmC. During 1952 was 14C was peak and subsequently reduced due to moratorium on tests.

The age of the water sample can be calculated by knowing the percent modern Carbon (pmC) but before arriving at conclusion several corrections are to be done. Factor such as chemical dilution and isotopic exchange, dissolved carbon of pure biologic origin and dissolved carbon of mixing origin needs to be considered.

Dissolved inorganic carbon species from the groundwater samples is obtained as Ba(OH)2 and it is used for radiocarbon measurement. After estimating the values of tritium, samples viz., OW21, OW24, BW5, BW20 and BW24 with less than 4 TU were selected for carbon dating. The analysis showed that some of the groundwater samples in Challaghatta valley are old water with a pmC values ranging 58 to 112.

ACKNOWLEDGMENT

The authors thank the Board of Research in Nuclear Science/Bhabha Atomic Research Centre (BRNS/BARC), Mumbai for providing facilities and financial assistance to undertake the work.

REFERENCES

APHA (2005). Standard methods for the Examination of water and wastewater. 21st Ed., Am. Public Health Assoc. Wash. DC.

Chebotarebv (1985). Metamorphism of natural waters in the crust of weathering. Cosmochim, Acta 8: 22-28.

Clark WB, Jenkins WJ, Top Z (1997). Determination of tritium by mass spectrometric measurements. Int. J. Appl. Radioactive Isotopes 27: 515-522.

Fritz P, Fontes JC (1980). Handbook of environmental isotope geochemistry. Elsevier, Amsterdam.

Handa BK (1969). Description and classification of media for hydro geochemical investigations. Symp. Ground water Studies in Arid and Semiarid Regions, Roorkee.

Joseph W (2001). Groundwater chemistry in the valley De Yabucoaallubial aquifer, Southeastern Puerto Rico. AWRA 3rd Int. symp. Trop. Hydrol. San Juan USA.

Mohapatra D, Das B, Chakrvortty V (2001). A co-rrelation study on physico-chemical characteristics of ground water in Paradipareas. Poll. Res. 20(3): 401-406.

Morteza S, Emaddedin F (2006). Tritium Concentration Study of Surface and Ground Water with a Specially Designed Proportional-counting Technique. Pak. J. Biol. Sc. 9(4): 681-685.

Nawlakhe WG, Lutade SL, Patri PM, Deshpande LS (1995). Ground

water quality in Shivapuri district in Madhya Pradesh. Ind. J. Env. Health 37(4): 278-284.
Plummer LN, Michel RL, Thurman EM, Glynn PD (1993). Environmental tracers for age dating young ground water. Alley, W.M., 1993, ed., Regional Ground-Water Quality, Van Nostrand Reinhold, New York pp. 255-294.
Plummer LN, Friedman LC (1999). Tracing and dating young ground water. U.S. Geological Survey Fact Sheet 4: 134-199.
Rambabu C, Somashekara Rao K (1986). Studies on the quality of bore well water by Nuzuid. Ind. J. Environ. Prot. 16(7).
Zouari K, Hkir N, Ouda B (2003). Palaeoclimatic variation in Maknassi basin (central Tunisia) during Holocene period using pluridisplinary approaches. Techni. Document IAEA, Vienna 2: 80-88.