

Full Length Research Article

THE TRITIUM CONTENT OF PRECIPITATION AND GROUNDWATER AT YOLA, NIGERIA

*ONUGBA, A¹. & *ABOH, H.O².

¹National Water Resources Institute, Mando, Kaduna Nigeria

²Department. of Physics, Kaduna State University, Kaduna Nigeria
hoaboh@yahoo.com

ABSTRACT

Tritium is a radioactive isotope of hydrogen which occurs in precipitation. In groundwater studies tritium measurements give information on the time of recharge to the system; the tritium content of precipitation being used to estimate the input of tritium to the groundwater system. At Yola, the tritium contents in precipitation and groundwater samples from boreholes were measured during the rainy season for 2 consecutive years. In the precipitation it was found to be 9.8 ± 0.8 TU. In the groundwater the tritium content ranges from 3.0 to 9.0 ± 0.8 TU. These values indicate that the groundwater systems around Yola contain a mixture of old recharge and recent recharge i.e. water younger than 50 years.

Keywords: Tritium, Groundwater, Tritium Units, Yola, Isotopes.

INTRODUCTION

All over the world, the growing need and continuing emphasis on the development of groundwater resources has stimulated the advent of several useful techniques in groundwater investigations based on the application of isotopes. Isotope hydrology provides complementary information on the type, origin and age of groundwater.

The isotope techniques used in hydrology may be classified into three groups: environmental isotopes, artificial isotopes and application of sealed radioactive sources. However, hydrogeological studies have come to rely increasingly on the application of environmental isotope techniques. The advantage of the environmental tracers, be they natural or anthropogenic, is that they provide in-situ information at the moment of sampling.

The most commonly used environmental isotopes are oxygen-18, deuterium, tritium, carbon-13 and carbon-14 (Pearson, 1991). This paper deals with tritium (^3H) content in natural waters in Yola metropolis. The ^3H content in groundwater can be used as a guide to distinguish between old water and recent waters containing at least a contribution of recent precipitation.

Tritium is a radioactive isotope of hydrogen which occurs in precipitation and originates from two sources, one natural and the other man-made. It is naturally produced in the upper layers of the

atmosphere from the action of cosmic rays on nitrogen according to the reactions:



The ^3H is rapidly oxidized and enters into hydrologic cycle as "tritiated" water. The production rate of ^3H in the whole atmosphere has been estimated at 0.25 atoms/cm²/s (Fontes, 1983). The concentrations in precipitation arising from this source vary between about 5 to 20 TU (Tritium Units) depending on the geographic location in the northern hemisphere. It generally increases with increasing latitude (IAEA, 1983).

The second source of tritium is man-made and has been derived since 1952 mainly from thermonuclear explosions in the atmosphere (Fontes, 1983). This atmospheric testing injected periodic pulse of ^3H into the atmosphere so that the concentration in precipitation increased by three orders of magnitude in the northern hemisphere in 1963/64 above that arising from the cosmic rays (Cook and Herezeg, 2000). However, since the middle 1960's the concentration has decreased to the so-called pre-bomb level, most especially in the developing countries where there are no nuclear facilities which might locally affect the present picture.

MATERIALS AND METHODS

Study Area: Yola, the capital of Adamawa State, Nigeria is a rapidly developing cosmopolitan town of over 50 km², with the population exceeding 150,000 by 1985 estimate (Zira, 1986). The town is situated in the semi-arid belt of Northern Nigeria. It lies along the Benue River with 9° 10' N to 9° 15' N and 12° 20' E to 12° 30' E, in the narrow arm of the Upper Benue Valley (Fig. 1). The area is generally flat to gently undulating. The elevation ranged from 160 to 190 m above sea level.

The climate is characterized by two distinct seasons; the wet and dry seasons of nearly the same duration. During the wet season, monsoonal rains fall between April and October. For the period 1956-87, the yearly mean was 952 mm and the average intensity per year ranged from 640 to 1300 mm. 75% of annual precipitation fell during July-September months. The annual amount of precipitation decreases with year. The dry season lasts from November to April (Adefolalu, 1986; Onugba, 1990).

The drainage system is dominated by the Benue River. There are several shallow wet season streamlets/rivers which issue as sea pages from rocks and dissect parts of the town.

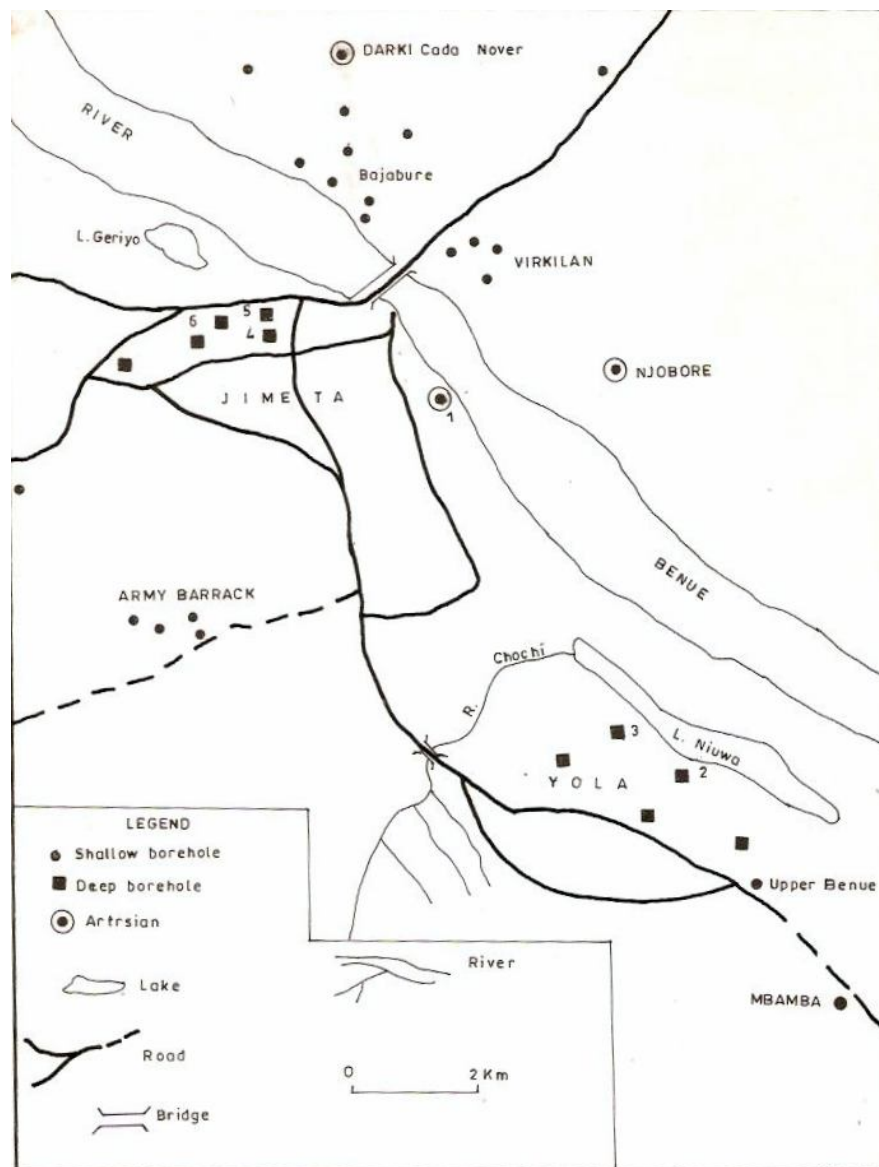


FIG. 1. MAP OF YOLA METROPOLIS SHOWING THE SAMPLING POINTS

Also several ponds exist, prominent among which are Lake Geriyo and Lake Njuwa. The streams and ponds generally drain into the Benue and do not survive the dry season. Evapotranspiration considerably exceeds precipitation as no permanent surface water exists except the Benue River. These phenomena also explain the large dependence on groundwater supplies in the area. For this reason and because of its location in a semi-arid belt, more than 93% of water supply comes from groundwater resources tapped by deep boreholes. Thus, information on its groundwater recharge is very critical for groundwater management.

Geology and Hydrogeology: The area is covered by light reddish to brown sandy soils underlain by the Cretaceous Bima Sandstone and Yola Sandstone. According to Preez and Barber (1965) the Bima Sandstone and Yola Sandstone cannot be separated

lithologically. They constitute a single formation here referred to as the Bima-Yola Sandstone. It is generally light brown, medium to coarse grained and distinctly feldspathic. Outcrops of the Bima-Yola Sandstone are massive in places and in other places they exhibit cross stratification which display alternation of coarse and fine grained bands. The entire formation rests unconformable on the Precambrian Basement which outcrops 13 km south of Yola. They all dip north east at low angles. The medium grained Bima-Yola sandstone disappears under the alluvium of Mayo Chochi (between Jimeta and Yola) and under that of the Benue on the North and NE of Jimeta-Yola (Offodile, 2002)

Hydrogeologically, the Bima-Yola Sandstone formation is the main source of groundwater supply. Water here occurs under both water-table and pressure water conditions. Open dug wells exploit

the phreatic aquifers while relatively deep boreholes (60 – 240 m depth) penetrate the confined/semi confined aquifers. Water under sub-artesian conditions have been encountered in several parts of the metropolis yielding 11000 to 20000 litres/hr. The Lithology logs of typical boreholes in Jimeta-Yola area is shown in Fig. 2.

The section is mainly an alternation of medium-to-coarse-grained sandstone with thin clayey material and medium-to-coarse grained sand associated with partially indurated sandstones of variable thickness. The loose sand and friable sandstones form the aquifer and intra-formational clays (or clayey intercalations) the aquiclude.

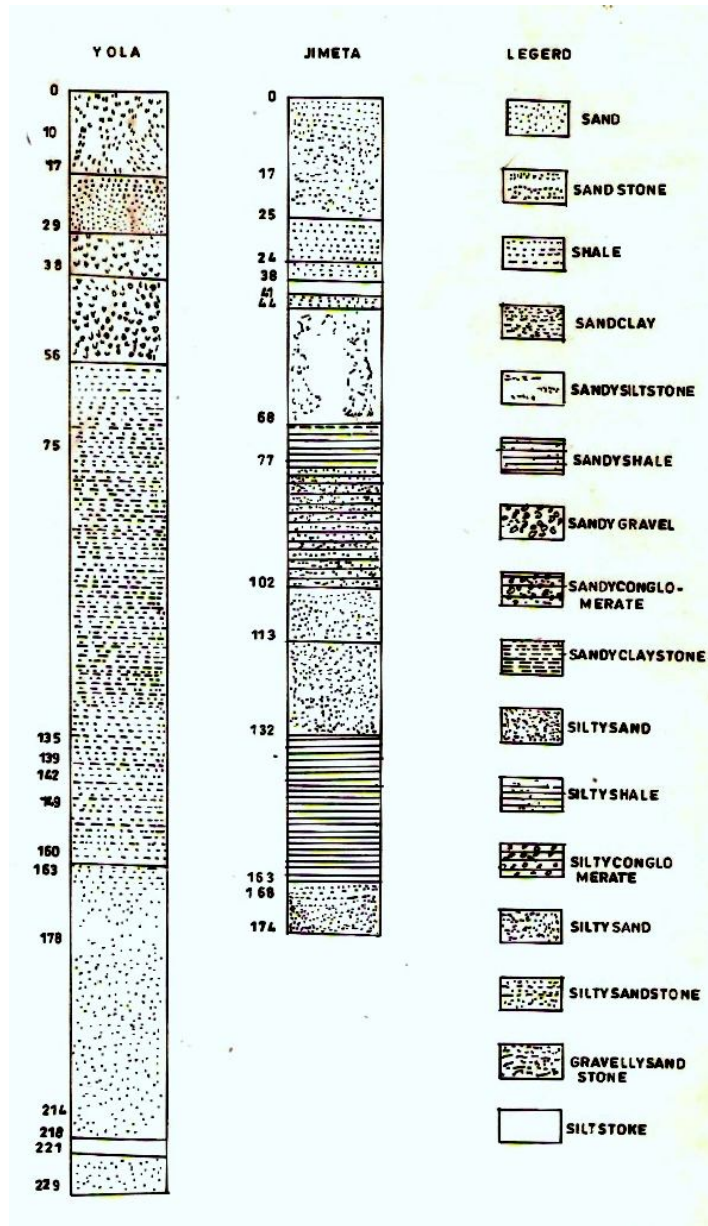


FIG. 2. TYPICAL BOREHOLE LOGS AT JIMETA AND YOLA

RESULTS

Water Sampling and Analyses: The rainfall at peak in the month of July/August was collected in a big container. An aliquot among of 500 ml was transported in 500 ml plastic bottles to France for tritium analyses. A similar procedure was repeated for the rainfall of July-August in the following year. At the same time, 500 ml of groundwater samples from deep boreholes (4 from Jimeta and 3 from Yola, (Fig. 1)) were also collected and carried to

France for analysis. All the tritium analyses (following standard procedure) were realized by liquid scintillation counting on PACKARD counter at the Centre de Recherche Geodynamique, Thonon, France. The results of the tritium analyses are presented in Table 1. Fig. 3 is a typical curve representing the variations of weighted monthly tritium content of precipitation at N'djamena and Kano from IAEA records (IAEA, 1981). Fig. 4 is the tritium content of groundwater sample plotted against borehole depths

TABLE 1. TRITIUM CONTENTS IN NATURAL WATERS AT JIMETA-YOLA

	Station	Location of Borehole Sampled	Year	Depth (m)	Tritium Level TU	Static Water level
Ground waters	1.	Mbamba	2008	208	3.6 ± 0.8	19.70
	2.	Yola BH7	"	120	9.3 ± 0.8	11.20
	3.	Yola(Damane)(BH23)	"	192	4.9 ± 0.8	8.40
	4.	Jimeta BH2	"	-	5.7 ± 0.8	-
	5.	Jimeta BH5	"	164	3.0 ± 0.8	3.01
	6.	Jimeta BH6	"	165	3.0 ± 0.8	9.72
	7.	Jimeta W/works	"	140	5.0 ± 0.8	5.07
Rains		Yola Upper	Jul 07		9.0 ± 0.4	
		Benue	Jul 08		9.8 ± 0.8	
		Garkida	Jul-Aug 08		11.0 ± 1.5	

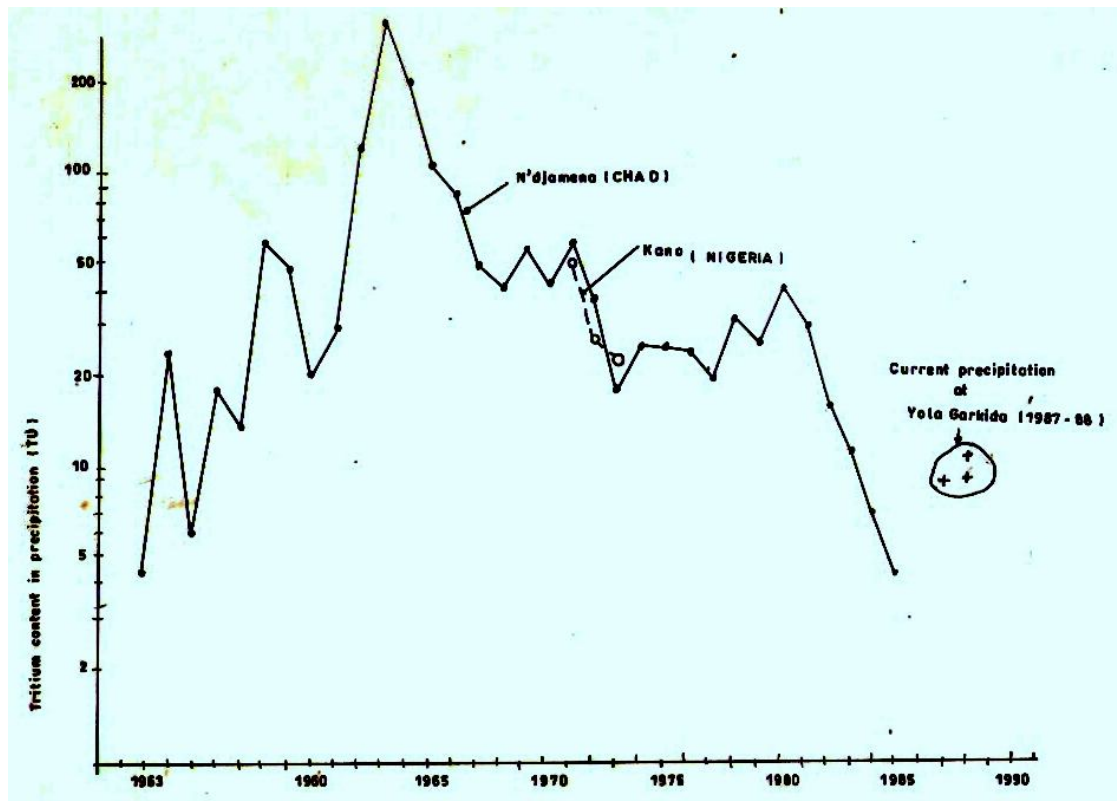


FIG. 3. VARIATION OF TRITIUM AT PRECIPITATION AT NDJAMENA, KANO AND YOLA

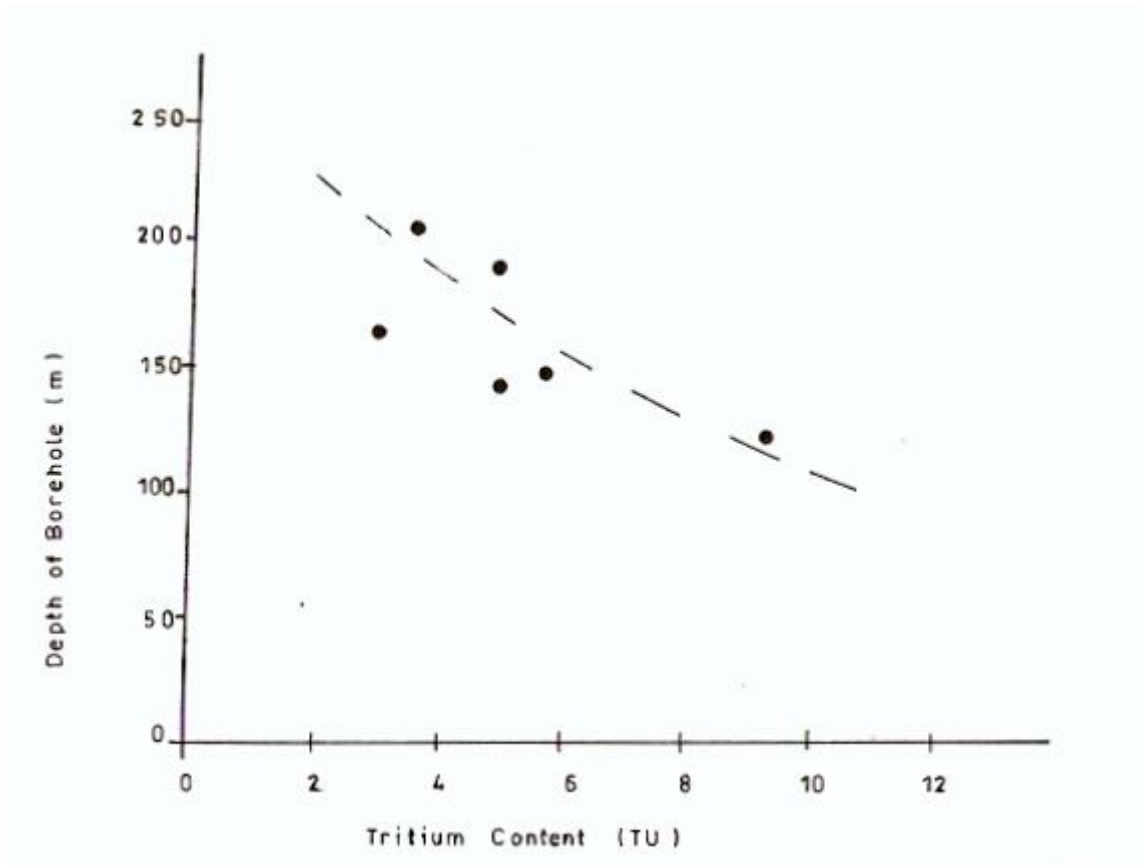


FIG. 4. VARIATION OF TRITIUM CONTENT IN GROUNDWATERS WITH DEPTH FOR DEEP BOREHOLES AT YOLA

DISCUSSION

Tritium in Precipitation: As shown in Table 1, the tritium contents in precipitation at Yola (Upper Benue meteorological station) were practically the same in the two consecutive years. The values were 9.0 ± 0.4 and 9.8 ± 0.8 TU respectively. At Garkida, situated 160 km north of Yola, the tritium in July-August precipitation of the first year was 11.0 ± 0.8 TU.

In several parts of the world the IAEA monitored the variations of ^3H and the stable isotopes (^{18}O , ^2H) in monthly precipitation. One of the IAEA stations with long data on ^3H in precipitation near to us is a Ndjamena (Chad). In Nigeria, the IAEA maintained a station at Kano from 1961 to 1973. The values presented on the curve representing the variations of weighted monthly tritium content of precipitation at N'djamena and Kano from IAEA records (IAEA, 1981) have been corrected for radioactive decay; the calculation covers the period from 1952-2008. It was observed from Fig. 4 that peak concentrations (in the West Africa Sub-region, at N'djamena) occurred in 1963/64 and has fallen steadily to the pre-bomb level. As can be seen on the curve, the ^3H content of current precipitation at Yola is not so much above the normal (pre-bomb) level of 4 to 20 TU. These values may represent the present recharge at Yola. The knowledge of the tritium content of precipitation is a pre-requisite for estimating the input function in a given area for interpreting tritium concentrations in groundwater in that area.

Tritium in Groundwater: The tritium content in groundwater samples from Jimeta and Yola are presented in Table 1. The Values range from 3.0 to 9.3 ± 0.8 TU. These values are rather low. When the water is shown to have a significant tritium, the

water is either of sub-recent age (younger than 50 years) or more likely a mixture of older and recent waters (Fontes & Edmunds, 1989).

As has been noted already, the tritium content of precipitation was used to estimate the input of tritium into groundwater system. The last pre-bomb precipitation occurred in 1951. The natural tritium content in precipitation which was then between 4 and 20 TU has now decayed down to about 1 to 4 TU in the 1980's (Fontes, 1983). Thus the practical rule to identify old groundwater (age > 50 years) would be ≤ 4 TU or even ≤ 9.0 TU at Yola; and tritium content of 10 – 50 TU would correspond to recharge between 1959 and 1971; tritium content of 50 – 300 TU would be the recharge during 1963 – 66 (obviously of recent origin). This rule assumes no mixing but that the groundwater remain quite discretely segregated according to age during transit. And if we accept this rule, then no water younger than 40 years is present in the boreholes sampled at Mbamba, Jimeta (station 5 and 6). This would mean that more than 40 years is required for water to reach the sampling points from the recharge area. These aquifers would then contain pre-bomb recharge. This is important for water resources management. In practice, however, mixing between different water bodies may take place because of depressive effect of the granular aquifer material, such that ^3H peaks and valleys could be smoothed out. Where mixing takes place, Fontes & Edmunds (1989) observed that no simple "recipe" can be given on the minimum ^3H value required to provide evidence of a significant contribution of recent water in an aquifer. In that condition the low or the lack of ^3H does not necessarily preclude present day recharge because transit time in the unsaturated zone may be considerably longer than 30 – 40

years; alternatively recharge may occur laterally. The arrival time of the TU peak is dependent on infiltration percolation characteristics and on the thickness of the unsaturated zone above the water table. An assumption may thus be made of homogeneous TU values in the saturated zone resulting from mixing of waters of different recharge due to depressive effect of aquifer granular material.

In the area studied, the borehole logs indicate stratified aquifer system whereby the water samples pumped from boreholes are mixture of three or more groundwater of different ^3H contents and origin/ages. In Fig. 4 tritium content of groundwater sample have been plotted against borehole depths. An examination of the measurement results indicates a decrease in concentration with increasing depth. This would be expected if good mixing (of young and old waters) is responsible for the variation in ^3H content in the groundwater samples. The mixing is probably taking place in the borehole or by hydraulic connection (leakage) between the different aquifer strata. A small portion of recent water combined with a major portion of ^3H free water may look like old water or small amount of thermonuclear ^3H present.

The ^3H content of current recharge (Fig. 4) is not much above the natural level. This introduces ambiguity in the interpretation of ^3H data. In that case a solution may be found in measurements of ^{14}C content of groundwaters. According to Fontes & Edmunds (1989), the thermonuclear ^{14}C due to its negligible decay over a time scale of some tens of years provides an alternative label of the recent recharge. The reason is that both ^3H and ^{14}C are produced by similar reactions in the atmosphere. The ^{14}C has a half-life of 5700 years compared to ^3H which has 12.43 years. The production of ^{14}C in the northern hemisphere by the detonation of nuclear explosives caused the atmospheric ^{14}C atmospheric content to be about double in 1963 (Clark & Fritz, 1997). Since then it has fallen but still remains above the pre-bomb level. Thus if ^3H correlated with a low ^{14}C content of dissolved inorganic carbon, the lack of ^3H will indicate that the groundwater system is discharging old waters. The question of recharge of both deep and shallow aquifers systems is one of the most critical for groundwater management in the arid/semi-arid areas. It is important to know if recharge is currently taking place and at what rate. Another problem groundwater hydrologists face in Nigeria is the poor knowledge of the recharge zone and of the flow system because of lack of observation points or because natural flow patterns are extensively modified by withdrawal.

Experience gained from the application of environmental isotope techniques over the past two decades has demonstrated that they could be especially well suited to investigation in the arid/semi-arid areas of Nigeria.

The ^3H content of a groundwater can be used as a guide to distinguish between old (pre-bomb water, older than 40 years) and waters containing at least a contribution of recent precipitations.

The tritium content of current precipitation/recharge measured at Yola is seen not to be much above the pre-bomb level. The tritium content measured in groundwater samples are below the values for current precipitation.

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