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## CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

# Analysis of isotope element by electrolytic enrichment method for ground water and surface water in Saurashtra region, Gujarat, India

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**Abstract:** The present study has been aimed for the assessment of isotope element Tritium (<sup>3</sup>H). It is a great threat to human health and environment for lengthy duration. The tritium exists in earth in diverse forms such as (1) small amounts of natural tritium are produced by alpha decay of lithium-7, (2) natural atmospheric tritium is also generated by secondary neutron cosmic ray bombardment of nitrogen, (3) atmospheric nuclear bomb testing in the 1950s, although the contribution from nuclear power plants is small. Tritium or <sup>3</sup>H is a radioactive isotope of hydrogen with a half-life of  $12.32 \pm 0.02$  years. Water samples from ground water, surface water, and precipitation were collected from different locations in Gujarat area and were analyzed for the same. Distillation of samples was done to reduce the conductivity. Deuterium and Hydrogen were removed by the process of physico-chemical fractionation in the tritium enrichment unit. The basis of physico-chemical fractionation is the difference in the strength of bonds formed by the light vs. the heavier isotope of a given element. A total of 10 cycles (runs) were executed using Quintals process. Tritium concentration files were created with help of WinQ and Quick start software in Quintals process (Liquid Scintillation Spectrometer). The concentration of tritium in terms of tritium units (TU) of various samples has been determined. The TU values of the samples vary in the range of 0.90–6.62 TU.

**Subjects:** Environmental Health; Pollution; Water Engineering; Water Science

**Keywords:** tritium; isotope; half-life; groundwater; deuterium; hydrogen; environmental sustainability engineering

### ABOUT THE AUTHORS

Sajal Singh (M Tech Environmental Science & Engineering), research completed at National Institute of Hydrology (Ministry of Water Resources), Roorkee (IIT Campus). Research and development work of the monitoring to effluent treatment plant, sewage treatment plant, common effluent treatment plant, and other water and wastewater sources. His research interest includes the treatment of the typically contaminated water and wastewater treatment. Athar Hussain is currently an associate professor at Ch. B.P. Govt. Engineering College, Jaffarpur, Delhi, India. His research interest includes water and wastewater treatment. He is specially focused on biological treatment of wastewater.

### PUBLIC INTEREST STATEMENT

Present study has been aimed to determine the concentration of the tritium from different sources of water. Because most of tritium is disseminated in the environment as water, it enters the hydrologic cycle as precipitation and eventually becomes concentrated in levels detectable in groundwater. It is a great threat to human health and environment for lengthy duration. Environmental tritium is a powerful tool for quantitative groundwater and surface water research, because it is a useful tracer for groundwater movement. Deuterium and Hydrogen were removed by the process of physico-chemical fractionation in the tritium enrichment unit. A total of 10 cycles (runs) were executed in Quintals process. Tritium concentration files were created with help of WinQ and Quick start software in Quintals process (Liquid Scintillation Spectrometer). Classification: Environmental Engineering, Water treatment.

## 1. Introduction

Tritium (T) or  $^3\text{H}$  is a radioactive isotope of hydrogen (having two neutrons and one proton) with a half-life of  $12.32 \pm 0.02$  years, decays to  $^3\text{He}$  emitting a beta particle having a radiation energy of 0.0057 MeV. Tritium concentration is measured in tritium units (TU). One TU is defined as the presence of one tritium in  $10^{18}$  atoms of hydrogen (H). In the earth, small amount of natural tritium is produced by alpha decay of lithium-7 (Kumar & Somashekar, 2011). Natural atmospheric tritium is also generated by secondary neutron cosmic ray bombardment of nitrogen. Tritium atoms then combine with oxygen, forming water that subsequently falls as precipitation. The extent of water/rock interaction, and hence the groundwater chemistry (Grahame, Manrico, & Offer, 1986), depends on the mineralogy of the aquifer rock and the residence time that the groundwater has been in contact with the rock. Prior to atmospheric nuclear bomb testing in the 1950s, tritium's natural average concentration ranged from approximately 2–8 TU. Since cessation of atmospheric nuclear tests, tritium concentrations have dropped between 12 and 15 TU, (Blavoux et al., 2013) although small contributions from nuclear power plants occur. Because most of tritium is disseminated in the environment as water, it enters the hydrologic cycle as precipitation and eventually becomes concentrated in levels detectable in groundwater.

Any possible health effects from tritium are the result of the beta radiation it emits. Because tritium's radiation cannot penetrate the skin, the only real exposure a person receives is the radiation received while tritium is inside the body. Exposure time and thus the possibility of health effects of the tritium depend on the form of tritium present, elemental tritium gas or tritium oxide. Tritium primarily enters the body when people drink tritiated water. People may also inhale tritium as a gas or absorb it through their skin, but exposure to harmful levels of tritium through these exposure pathways is very unlikely. Once tritium enters the body, it is quickly and uniformly distributed throughout the body, going directly into soft tissues and organs. The associated dose to these tissues is generally uniform and dependent on the tissues' water content. Regardless of the way it enters the body, tritium oxide immediately mixes with the body fluids and is eliminated like normal water (Stamoulis, Karamanis, & Ioannides, 2011). When it passes through a human body, it can produce permanent changes in cells. There are three principal potential health effects: cancer, genetic effects, and effects on fetuses. The body removes tritium naturally in the same way it removes water—by excreting it in the urine. As with all ionizing radiation, in theory, we assume exposure to tritium could increase the risk of developing cancer.

Tritium does not totally harmfully for human being, but it is also advantageous to water research. Environmental tritium is a powerful tool for quantitative groundwater and surface water research, because it is a useful tracer for groundwater movement. The age of water can be defined with help of tritium concentration (Iwatsuki, Xu, Itoh, Abe, & Watanabe, 2000). However, it is not possible to determine the correct age of groundwater by measuring the tritium concentration alone, but one should have other information about the aquifer in question and the flux of water. Tritium concentration in precipitation varied quite a lot during the last forty years due to atmospheric nuclear tests. Usually ground water will be mixture of many year input of tritium concentrations (Colville, 1984). If the tritium concentration is zero, then we can say that the water is old and has been cut off from the atmosphere for more than 50 years.

The tritium distribution in the groundwater is determined by (1) the input functions for the tritium concentration in recharge water, (2) the movement and mixing of water within the saturated zone (Cheng et al., 2010). Both the above factors have to be addressed when using the tritium concentration to estimate the age of water. The aim of this paper is to assessment of isotope element (tritium) of different sources of water. To meet these objectives, water samples from ground water, surface water, and precipitation were collected from different location in Gujarat area and were analyzed. The samples are provided by NIH.

## 2. Materials and methods

### 2.1. Sources of samples for tritium analysis

Typically, for environmental tritium analysis an aliquot of one liter is sufficient. The samples were collected as raw unfiltered water with no preservatives and stored either in a glass or high density polyethylene bottle with air-tight caps. Samples were given a unique sequential number and their description (i.e. sample, source type, location, etc.) and logged into a record book for reference.

A total number of 16 samples were collected and analyzed. The samples were collected from various sources such as hand pump, piezometer, and surface water from Saurashtra region. Saurashtra region is located in Gujarat state of India. The hand pump samples represent the shallow aquifer while piezometer samples represent deep aquifer. Initial analysis indicated that the samples had very high conductivity which is not enviable for tritium enrichment process. Conductivity of all samples to be analyzed should always be less than 100  $\mu\text{S}/\text{cm}$  for carrying out tritium enrichment process. Therefore, distillation of the samples was done to reduce the conductivity. The distillation process was repeated three times till the desired conductivity levels were attained. Details of the various samples are given in Table 1.

The four steps involved in the process of tritium analysis are:

(1) Pre-distillation of sample, (2) Tritium Enrichment process, (3) Post-distillation of sample, (4) Quintals process. The various steps are discussed below.

### 2.2. Pre-distillation of sample

The samples were distilled (primary distillation) in the laboratory to remove all dissolved salts a pre-requirement before further processing. The various ions that are naturally found in water ( $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{CO}_3$ ,  $\text{Mg}^{++}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ , etc.) could interfere with the electrolysis process (i.e. produces gasses at either the

**Table 1. Details of all the samples collected along with different locations**

S. No.	Sample ID	Location	EC (I testing) ( $\mu\text{S}/\text{cm}$ )	EC (II testing) ( $\mu\text{S}/\text{cm}$ )	EC (III testing) ( $\mu\text{S}/\text{cm}$ )	Latitude	Longitude
1	JND-Pz-32	Khageshri	70	-	-	2,405,478	601,509
2	Pz-P-12	Adityana	300	60	-	2,399,341	567,817
3	JND-Pz-18	Ranavav	30	-	-	2,398,553	576,711
4	Pz-P-08	Ranavav	340	30	-	2,397,599	565,882
5	Pz-P-11	Mokar	1,310	80	-	2,387,885	580,535
6	Pz-P-02	Jambu	450	280	100	2,386,291	590,799
7	Pz-P-06	Kuchhadi	350	70	-	2,398,229	558,715
8	Pz-P-01	Mokar	420	170	70	2,389,970	581,307
9	JND-21	Rana kandorna	60	-	-	2,393,592	591,520
10	WS-2 creek near 3S-4	Tukda	320	60	-	2,82,173	574,511
11	Pz-P-10	Oddadar	220	100	-	2,386,552	572,478
12	Hand pump Khirasara	Khirasara	80	-	-	-	-
13	JND-Pz-17	Kantela	440	120	80	2,400,626	554,017
14	P5N-2	Kuchhadi	50	-	-	2,396,509	557,523
15	Pz-P-09	Chaya	20	-	-	2,391,779	565,670
16	WS-4	Oddadar	30	-	-	2,383,771	576,831

anode or cathode other than oxygen or hydrogen) and also corrode the mild steel electrode. It is important to note that not all salts need to be removed through primary distillation. If volatile salts or soluble gasses are present they could distill over with the water. When sample in distillation flask is nearly or completely distilled to dryness, turn off the heating unit check the conductivity of the distilled water sample. If it is up to 100  $\mu\text{S}/\text{cm}$  then place (Clark & Fritz, 1997) the distilled samples in a tightly sealed container. In case of saline samples, the conductivity of the distilled sample may be more than 100  $\mu\text{S}/\text{cm}$ . In such cases water samples should be distilled again.

### 2.3. Tritium enrichment unit

#### 2.3.1. Tritium enrichment system

The electrolytic enrichment is the simplest and provides relatively high enrichment compared to other technique. In the electrolytic enrichment unit, tritium in sample water is concentrated by low temperature electrolysis. The electrolytic enrichment system contains: (1) electrolytic cell, (2) constant current (DC) supply unit, (3) cooling unit.

The process of electrolysis is very slow. The tritium measurement involves enrichment of standards, local water as a secondary standard, and a background sample. Long measurement duration and large number of samples analysis necessitate electrolytic system large enough to accommodate sufficient number of electrolytic cells. The system in use at National Institute of Hydrology (NIH), Roorkee, India (since 11–12 years) accommodates 20 electrolytic cells in the unit. The electrolytic reduction is done to concentrate the tritium. The samples contain mainly HHO and HTO molecules. By passing electric current through a conducting water solution, the bonds of the water molecules are broken with evolution of hydrogen and oxygen (Kluge et al., 2010). The temperature of the sample is maintained between 0 and 5 C in order to achieve the maximum fractionation or enrichment of HTO.

#### 2.3.2. Electrolytic enrichment tritium theory

Electrolytic of water is a process in which water molecule dissociates into basic elements namely, hydrogen and oxygen on applying an electric field. During electrolysis, hydrogen appears at the cathode and oxygen at the anode. Similarly like hydrogen in case of HTO, tritium gets released at the cathode.

In the dissociation process lighter molecules get dissociated at a lower dissociation energy compared to that of heavier molecules (Gat, 1980). The molecules weight of HTO (20) is 2 units higher as compared to the molecules of  $\text{H}_2\text{O}$  (=18). Therefore on electrolysis the  $\text{H}_2\text{O}$  dissociates much rapidly compared to HTO molecule. This differential rate of dissociation leads to enrichment of HTO molecule in the water phase. The process therefore not only dissociates water into their respective gasses with the observed depletion in the quantity but also relatively enriches HTO molecules with respect to  $\text{H}_2\text{O}$  molecule in the liquid phase. In fact, the parameters like supplied electrical energy, reduction in the water amount, and enrichment of HTO in water phase are directly related.

The enrichment is also expressed in terms of isotopic ratio ( $^3\text{H}/\text{H}$ ) in water to vapor phase (or released gasses in the case of electrolytic enrichment) as,

$$\beta(^3\text{H})_{\text{water-vapor}} = \frac{(\text{water}^3\text{H}/\text{H})}{(\text{vapor}^3\text{H}/\text{H})} \quad (1)$$

Thus, the fractionation is the isotope concentration which is observed due to isotopic mass dependent control on the rate of physico-chemical reactions. The fractionation affects the individual isotope concentration in the reactant and product phase with no effect on the chemical nature of reactant or product of product species. The enrichment of deuterium and tritium is due to isotope effects that take place during electrolysis. Isotope fractionation occurs in any thermodynamic reaction due to

differences in the rates of reaction for different molecular species. The result is a disproportionate concentration of one isotope over the other.

### 2.3.3. Isotopic fractionation (thermodynamic and quantum mechanical explanation)

The basis of physico-chemical fractionation is the difference in the strength of bonds formed by the light vs. the heavier isotope of a given element. Difference in the bond strength for an isotope of the same element is because of the differences in their reaction rates. The zero point energy is essentially a minimum potential energy of a molecular bond in a vibrating atom. The dissociation energy is more for heavy isotopes as compared to the lighter isotopes. The difference in the dissociation energy affects their reaction rates with lighter isotope reacting rapidly as compared to heavier isotope (Kitaoka, 1981). Isotope fractionation during physico-chemical reaction arises from this differential rate of chemical reaction. Isotope fractionation during physico-chemical reactions arises from the difference itself.

During the phase transition process, the dissociation energy relates to the partition function  $Q$  by the relation:

$$Q = \sum \sigma^{-1} m^{3/2} e^{-E/KT} \quad (2)$$

where  $\sigma$  is the asymmetry value,  $m$  is the isotopic,  $E$  is the energy state (in J/mole),  $\Sigma$  is the summation taken over all energy states from the point energy to the energy of the dissociated molecule,  $K$  is the Boltzmann's constant (gas constant per molecule),  $T$  is the temperature in Kelvin.

## 2.4. Distillation of enrichment samples (secondary distillation)

### 2.4.1. Use of lead chloride in post distillation

This is done to remove the  $\text{Na}^+$  that got added through addition of  $\text{Na}_2\text{O}_2$ . The sample is transferred into a 50-ml round bottom flasks, then 8 g of  $\text{PbCl}_2$  is added. Thereafter, condenser and collector are connected and the distillation is carried out. The flask is kept heated even after the drying of water to recover all of the hydrogen.

## 2.5. Quintals process

### 2.5.1. Liquid scintillation spectrometer

Quantulus is an ultra-low level spectrometer which provides stable measurement conditions, where no atmospheric pressure correction is needed even during long-term low radioactivity sample counting. The system includes PC software to allow complete data processing and the plotting of up to six spectra on screen. Liquid scintillation spectrometer is controlled by two PC software (WinQ and Quick start software).

Alpha, beta, and gamma radiation all fall into the category of ionizing radiation. Alpha and beta particles directly ionize the atoms with which they interact, adding or removing electrons. Gamma rays cause secondary electron emissions, which then ionize other atoms. The ionized particles left in the wake of a ray or particle can be detected as increasing conductivity in an otherwise insulating gas, which is done in electroscopes, ionization chambers or proportional counting chambers. These devices measure the pulse of conductivity between two electrodes when a particle or ray ionizes the gas between them. If a sufficiently high voltage is applied between the electrodes, an amplification of the signal can be obtained, and such counters can be quite sensitive. Their utility is severely limited by the fact that for most research applications only gas phase isotopes can be detected. This greatly complicates sample preparation and may preclude the analysis of some compounds entirely.

### 2.5.2. Observations

Counting is carried out in polyethylene scintillation vials. For this 8 g of enrichment sample/spike/background is mixed with 13 g of Ultima Gold LLT. Sample was prepared for counting containing the standards STD-B and STD-C (two vials each), three vials of tritium free water and all the enriched samples (Saito, Shimamune, Nasik, Schimizu, & Hayashi, 1996). Special activity was being calculated as count per minute per gram of sample weight. The vials were placed in counter trays in the three pre-planned positions corresponding to the plan previously entered in the quantulus logbook. The standard and Tritium-Free vials were placed in a spatially distributed manner. The whole counting was being done in 10 cycles. Each vial has been counted for 40 min in each cycle thus each sample is counted for a total time of about 400 min.

The cycling helps in averaging any change that may occur such as lose of sample/cocktail weight, change in counting characteristics of the scintillator, change in counter stability, etc., which affects the sample count rate. This also helps in discarding any particular data, which is not statistically acceptable. Allow sample to remain in the counter for 24 h prior to the counting in order to adjust to counter temperature. The quantulus machine is operated through the WinQ and Quick start software.

### 2.5.3. Estimation of tritium concentration

The spiked samples estimation with tritium has been carried out. Out of all electrolytic cells, any three cells were used for enriching tap water samples spiked with tritium activity at another three for blank tap water sample. The spiked samples were meant for determining their tritium enrichment factor “Z” (final tritium concentration/initial tritium concentration). C.B. Taylor, I.A.E.A. has developed the following equation for the estimation of tritium enrichment factor of unknown samples.

$$\frac{\ln Z}{\ln N \cdot r_a} = \left(1 - \frac{1}{\beta}\right) + \frac{r_c}{r_a} (1 - d) \quad (3)$$

where  $r_a$  is the rate of electrolysis/total loss rate of hydrogen from cell,  $N$  is  $W_0/W_f$  (initial weight of the sample/final weight of the sample),  $\beta$  is instantaneous electrolytic separation factor for tritium,  $r_c$  is the rate of hydrogen loss as water vapor/total loss of hydrogen from cell,  $d$  is the fractionation factor for loss of tritium by evaporation.

On the right-hand side of Equation (3) the second term is of order of 0.5% of the first term. The variation from cell to cell is negligible if it is based on a same set operated under the similar conditions (Michael, 2012). Equation (3) therefore indicates that a set of cells with uniform separation factor assigned as the symbol  $\beta$  when run simultaneously should show uniformity for the parameter  $\ln Z/r_a$   $\ln N$ . This parameter  $E$  should be used to evaluate enrichment factor, and to monitor the performance of a set of batch electrolysis cells. With slight modification in Equation (3), enrichment parameter  $E$  may be represented by Equation (4):

$$E = \left[ \frac{W_0 - W_f}{W_e} \right] \frac{\ln Z}{\ln N \cdot r_a} = \left[ \frac{W_0 - W_f}{W_e} \right] \left(1 - \frac{1}{\beta}\right) + \frac{r_c}{r_a} (1 - d) \quad (4)$$

where  $(W_0 - W_f)$  is the total weight loss of the sample due to electrolysis evaporation and spray losses and “ $W_e$ ” is the weight of electrolyzed water. If “ $W_e$ ” cannot be measured accurately in the absence of an accurate ampere hour meter, then it can be made constant for all cells by passing series current for the same time. Because the second term on the right-hand side of Equation (4) is so small, the separation factor  $\beta$  is the parameter which mostly affects the magnitude and variability of the enrichment parameter  $E$ . In the case of spike samples,  $Z$  is measured and applied to determine  $E$ ; the mean value “ $E_m$ ” of  $E$  of the three samples, is then used to calculate  $Z$  for the unknown sample. If the total charge passes  $Q$  A h, then



$$W_e = \frac{Q}{2.97545} \quad (5)$$

Since the same amount of current is passed through all cells in series for the same length of time, the modified enrichment parameter,  $W_e E$  is used for the calculation of  $Z$  of unknown sample.

$$W_e E = [W_0 - W_f] \frac{\ln Z}{\ln N \cdot r_a} \quad (6)$$

Therefore,

$$\ln Z = [W_0 - W_f] \cdot [W_e E_m \ln N] \quad (7)$$

where  $W_e E_m$  is the mean enrichment parameter of the three spiked cells, and  $N$ ,  $Z$  and  $(W_0 - W_f)$  are the mass reduction factor, tritium enrichment factor and total weight loss of the unknown sample (due to electrolysis, evaporation, and spray losses), respectively. The separation factor  $\beta$  for a spiked cell can be calculated using the equation,

$$B_{\text{eff}} = \ln \left( \frac{W_f}{\ln \left( Z \cdot \frac{W_f}{W_0} \right)} \right) \quad (8)$$

The tap water sample is enriched mainly to determine the background count rate of spiked samples. This has become necessary as large quantity of tritium-free water is always not readily available to prepare the spike samples.

As the three spike cells are changed in rotation one after another in each run, one gets the enrichment parameter values of every cell which is found to be uniform if the cathode surfaces are well developed and unaffected by corrosion, chemical damage, mechanical damage, etc.

The tritium concentration of a sample on counting data is calculated as

$$C_s = C_{st} \cdot \left( \frac{N_s}{N_{st}} \right) \cdot \frac{1}{Z} \quad (9)$$

where  $C_s$  is the tritium concentration in TU of the sample,  $C_{st}$  is the tritium concentration in TU of the standard,  $N_s$  is the net count rate of the sample,  $N_{st}$  is the net count rate of the standard.

### 3. Results and discussion

A total of 10 cycles (runs) were completed in liquid scintillation spectrometer. The registry file of each cycle of samples was created with the help of WinQ software. The registry files so created are being run in quick start software. Using this software, the tritium concentration in Cpm (count per minute) unit was found. The tritium concentration file in Cpm was then run in WinQ software and the tritium concentrations in TU (Tritium Unit) were determined. Details of result of various samples are given in Table 2.

Data summarized in Table 3 indicate a high concentration of tritium in ground water in maximum samples. The tritium concentration values range between 0.90 and 6.62 TU (Figure 1). Ranavav region water contains a high concentration of tritium as compared to the other samples of different regions. The Jambu region water contains a lowest concentration of tritium as compared to other samples. While both regions located in Saurashtra are, of Gujarat. But tritium concentration of all samples is greater than exposure limit. Therefore, this water is very harmful for living organism.

The tritium concentration can be used as a powerful tool for quantitative groundwater research and rain water research. The radioactive element decaying time can be determined using half-life

**Table 2. Analysis details of samples collected at different locations**

S. No.	Sample	Code	Enrichment date	Cpm	TU	TU error (±)
1	JND-Pz-32	20	16-May-13	1.08	1.97	0.40
2	PZ-P-12	20	16-May-13	0.89	1.17	0.36
3	JND-PZ-18	20	16-May-13	1.18	2.48	0.43
4	PZ-P-08	20	16-May-13	2.08	6.62	0.46
5	PZ-P-11	20	16-May-13	1.12	2.85	0.54
6	PZ-P-02	20	16-May-13	0.80	0.90	0.37
7	PZ-P-06	20	16-May-13	1.26	3.20	0.51
8	PZ-P-01	20	16-May-13	1.12	2.16	0.41
9	JND-21	20	16-May-13	1.12	2.31	0.53
10	WS-2 creak near 3S-4	20	16-May-13	1.24	3.13	0.62
11	PZ-P-10	20	16-May-13	1.02	1.97	0.53
12	Hand pump Khirasara	20	16-May-13	0.92	1.50	0.51
13	JND-Pz-17	20	16-May-13	0.93	1.32	0.39
14	P5N-2	20	16-May-13	1.05	1.69	0.44
15	PZ-P-09	20	16-May-13	0.84	1.00	0.43
16	WS-4	20	16-May-13	1.24	2.60	0.52

formula used for radioactive elements. But one should have other information like aquifer (confined and unconfined). The decaying of parent isotope activity (related to radiation emission rate) takes place at a systematic rate governed by equation:

$$A = A_0 e^{-\lambda t} \tag{10}$$

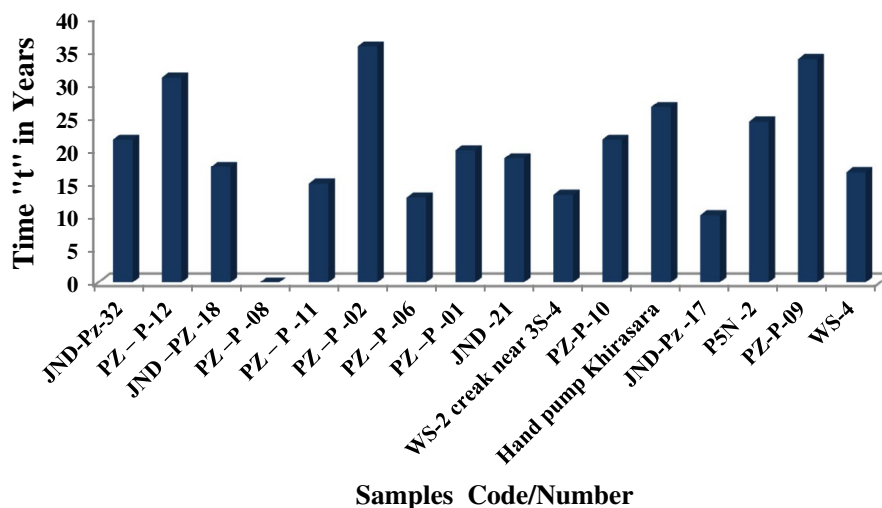
where  $A_0$  represents the maximum concentration of the tritium (for each sample) at initial period while  $A$  represents the concentration of the element at any time  $t$ .  $\lambda$  is the decay constant which is

**Table 3. Details of decaying time for various samples**

S. No.	Sample	Enrichment date	Tritium concentration in TU	Time (t) in years
1	JND-Pz-32	16-May-13	1.9	21.6
2	PZ-P-12	16-May-13	1.17	30.9
3	JND-PZ-18	16-May-13	2.48	17.5
4	PZ-P-08	16-May-13	6.62	0
5	PZ-P-11	16-May-13	2.85	15
6	PZ-P-02	16-May-13	0.90	35.6
7	PZ-P-06	16-May-13	3.20	12.9
8	PZ-P-01	16-May-13	2.16	20
9	JND-21	16-May-13	2.31	18.8
10	WS-2 creak near 3S-4	16-May-13	3.13	13.3
11	PZ-P-10	16-May-13	1.97	21.6
12	Hand pump Khirasara	16-May-13	1.50	26.5
13	JND-Pz-17	16-May-13	1.32	10.2
14	P5N-2	16-May-13	1.69	24.3
15	PZ-P-09	16-May-13	1.00	33.7
16	WS-4	16-May-13	2.60	16.7



Figure 1. Tritium concentration variations of all samples from different locations.



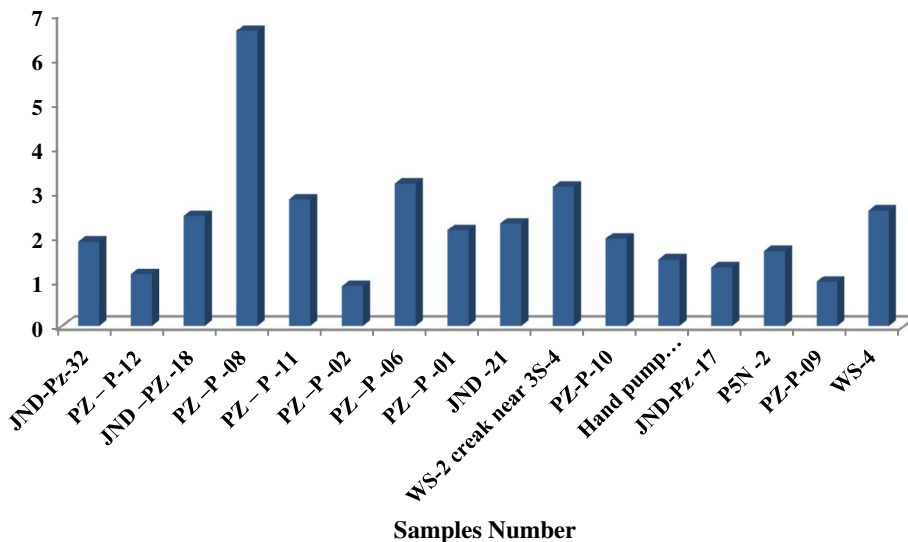
characteristic of an isotope. Other information should be available such as ground water flex, aquifer situation, etc. However, it is not possible to determine the time for decay of its initial strength of tritium concentration by measuring the tritium concentration alone (Motzer, 2007), but one should have other information like aquifer (confined and unconfined). Here,  $A_0$  denotes the maximum concentration of tritium depending on the aquifer condition. The study on ground water aquifer of Saurashtra region has already been carried out by the NIH. Based on that study it can be assumed that the  $A_0$  is the maximum concentration of the tritium within all samples.

$$\lambda = \frac{0.693}{t^{1/2}} \tag{11}$$

where  $\lambda$  is the decay constant which is characteristic of an isotope and is definite in terms of its half-life is denoted by  $t^{1/2}$ . This  $t^{1/2}$  is defined as the time in which the radioactive element decays to one half (1/2) of its initial strength. Half-life of the tritium is calculated as  $12.35 \pm 0.02$ .

From the present study, the time values of groundwater samples as calculated in the study area ranges between 0 and 35.6 year (Figure 2). The lower concentration of tritium indicates the old water or multiple birth of the present water and higher concentration of tritium indicates recently

Figure 2. Decaying time variations of tritium in samples from different locations.



generated water (Morgenstern & Daughney, 2012). It can be inferred that the tritium concentration is decreasing with respect to time in all the samples of present study area.

In Equation (12), A is determined experimentally through measurement of sample activity,  $A_0$ , the initial activity is estimated from combination of measured data and field data. On solving the Equation (12), the age can be calculated which is the time elapsed to decay the parent activity from  $A_0$  to A. For the case of  $^3\text{H}$  Equation (12) reduces to age equations as:

$${}^3\text{H age(Years)} = \frac{\ln A_0}{A} \quad (12)$$

#### 4. Conclusion

The samples from different sources such as hand pump and piezometer belonging to Saurashtra region of Gujarat were analyzed for tritium. The samples analysis was carried out in Nuclear Hydrology Laboratory at NIH, Roorkee. The experimental analysis of tritium involves four steps namely pre-distillation, tritium enrichment, post-distillation, and quintals analysis. The concentrations of tritium in all samples has been analyzed and quoted in terms of tritium unit (TU). The tritium concentration in all samples lies in the range from 0.90 to 6.62 TU. The obtained concentration values can be used to determine the age of the source of water. However, it appears that sample number 6 has added values of the samples.

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