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Determination of the origin and recharge process of water resources in Salda Lake Basin by using the environmental, tritium and radiocarbon isotopes (Burdur/Turkey)

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Research Article

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Stable isotope, Tritium, Radiogenic isotope, Salda Lake.

ABSTRACT

The Salda Lake basin which is in the southwestern Turkey is an important water body in view of environmental values. We used stable isotopes (δD and $\delta^{18}O$), $\delta^{3}H$ and ^{14}C composition of the water samples to understand recharge process effective in the groundwater and lake water. Water samples were collected in dry and wet periods and the stable isotope (δD and $\delta^{18}O$) and radiogenic isotope (^{14}C) analysis were made in the basin. The $\delta^{18}O$ contents of groundwater and lake water ranged from -9,94‰ to 1,18‰ in dry period and from -10,24‰ to 0,30‰, in wet period. δD contents of groundwater and lake water varied from -67,42‰ to 1,20‰ and from -64,51‰ to -2,80‰, in dry and period wet respectively. The stable isotope data of samples indicate a meteoric origin for all samples. According to stable isotope data, groundwater samples seem to be recharged from higher elevations whereas the lake water is recharged from low elevations. The tritium ($\delta^{3}H$) content of the water samples ranges from 1.04 to 4.49 TU and from 1.91 to 4.18 TU in the dry period and wet period respectively. Long-term $\delta^{3}H$ observations are required to determine whether these $\delta^{3}H$ signals are associated with young recharge or with the groundwater with long residence time. In addition, the ^{14}C activities of the samples vary between 90 pmc and 110 pmc for Salda Lake waters and 530 pmc and 5990 pmc for the groundwater.

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1. Introduction

Surface and groundwater perform an important function, the maintenance of the natural environment and ecosystems with a continuous recycling and renewal process of evaporation, precipitation and runoff in nature as well as supplying freshwater for human necessities such as agriculture, drinking water, industry and recreation (Çaldırak and Kurtuluş, 2018). Unfortunately, it is difficult to understand how the recharge processes in surface and groundwater. Therefore, the isotopes of oxygen $\delta^{18}O$ and hydrogen δD are used as major tracers for determining the origin and movement of groundwater (Subyani, 2004). The isotopic properties of oxygen and hydrogen are influenced by atmospheric and surface processes during recharge of the groundwater (Gupta and Deshpande, 2005). In addition to the environmental isotopes in groundwater studies as tracers of groundwater provenance and age, isotopes

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are also used to study the quality of groundwater, geochemical evaluation, water-rock interaction, the origin of salinity, recharge processes and contaminant processes. Also, tritium isotope (δ^3H) is always introduced into the hydrological circulation and dated with the fallout from atmospheric nuclear weapon tests conducted mainly during the early 1960s. It can be indirectly used to evaluate the rate of groundwater circulation and renewal rate (Clark and Fritz, 1997; Mokadem et al., 2017). Furthermore, the relationships between the physicochemical parameters and the isotopic properties of water are very important in understanding the recharging process of natural resources. (Baykal et al. 1996; Çaldırak and Kurtuluş, 2018).

In this study, the Salda Lake basin is selected as the investigation area. Because, Salda Lake within the basin is an important surface water in terms of environmental. Firstly, Salda Lake is one of the largest and deepest (about 184m) enclosed saline lakes of Turkey (Kazancı et al., 2004). It is highly alkaline (pH 8–10) and magnesium rich. Also, the magnesite deposits located around of the lake, were related to “White Rock” which was also discovered on Mars (Russell et al., 1999). Furthermore, in the Salda Lake basin, the groundwater which is recharge to Salda Lake, is used intensely as drinking, domestic and irrigation purposes. Therefore, the main purpose of the study is to reveal the origin and recharging of groundwater and surface water in the basin using the environmental isotopic, radiocarbon and physicochemical properties of water.

2. Materials and Methods

2.1. Study Area

The Salda Lake basin which is in the southwestern Turkey at 42 59404 - 44 4624N and 1799785 - 734837E and covers an area of 207.14 km^2 (Figure 1). Basin is an important water body in view of environmental values. The Salda Lake basin is a depression basin with closed basin characteristics, formed by the effect of tectonism at the end of Neogene (Lise et al., 2013). The Quaternary alluvium in the Salda Lake basin covers up to 34.84 km^2. The thickness of the aquifer is 5 to 60 m in the Yeşilova and its surroundings. The aquifer system is composed of sand, gravel, clay and mudstone levels (Table 1). The mean annual precipitation and real evaporation are approximately 494.10 mm and 345.91mm/year in the basin, respectively (Varol et al., 2017).

2.2. Sampling and Analytical Methods

Total 34 water samples collected from wells, springs, stream and lake waters were analyzed in November 2015 (dry period) and June 2015 (wet period) for the determination of their hydrochemical characteristics and their stable isotope (δD, $\delta^{18}O$, δ^3H and ^{14}C) composition in the study area. All sample’s locations were determined on Global Positioning System (GPS). Physical parameters (pH, temperature (T; °C) and electrical conductivity (EC; mS/cm)) of the water samples were measured in-situ with YSI Professional Plus multiparameter instrument (YSI 6050). Samples were collected in 100 ml clean polyethylene bottles and dispatched for analysis to the laboratory in an ice-filled box. The major cations were analyzed by ICP-MS (Inductively Coupled Plasma-Mass Spectrometer) at the Bureau Veritas Commodities Canada Ltd. (ACME Laboratory Vancouver, Canada, an ISO 9002 accredited company). CO_3^{2-} and HCO_3^-, anions were analyzed by titrimetric method; Cl^-, and SO_4^- were determined using ion chromatography at Water Chemistry Laboratory at Hacettepe University (Ankara, Turkey). The accuracy of the analysis can for major ions be estimated from the electrical balance (E.B.) since the sum of positive and negative charges in the water should be equal:

Electrical Balance (%) = (Sum cations + Sum anions)/ (Sum cations + Sum anions) x 100 [1]

Where cations and anions are expressed as meq/L and inserted with their charge sign. The sums are taken over the cations Na, K, Mg^{2+} and Ca^{2+}, and anions Cl, HCO^-_3 and SO_4^{2-} (Appelo and Postma 2005). In this study, E.B (%) was used to determine accuracy of the major ions analysis (Table 2).

Water samples for oxygen ($\delta^{18}O$), deuterium (δD), tritium (δ^3H), isotopic analysis was analyzed at the Hacettepe University International Karst Water Resources Research Center and for ^{14}C analysis was analyzed at Geochron Laboratories Massachusetts (U.S.A.). $\delta^{18}O$ and δD from isotopic compositions of the samples were determined using International Atomic Energy Agency (IAEA)-Equilibration method. Also, δ^3H was determined using IAEA-Liquid Siltation

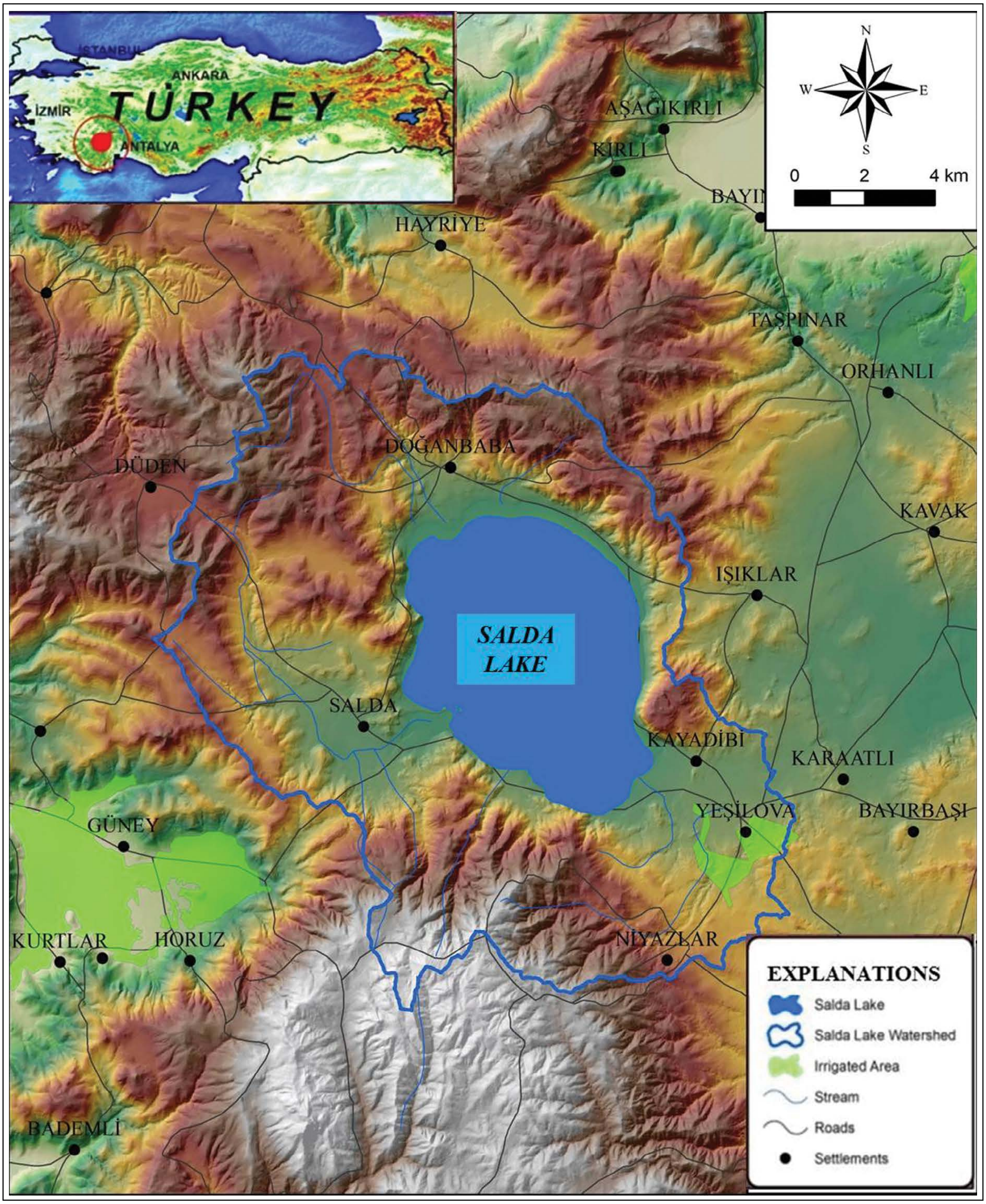

Figure 1- Location map of the study area (1/200.000 scale).

Counting (LSC) Technique. The amounts of Tritium (δ^3H) are determined as absolute concentrations, using tritium units (TU). The tritium unit is 1 TU = 0.1183 Bq/L. The precision of measurements is ±1 TU. Determination of natural radioactivity in drinking water samples were used EPA 900.0 method.

Table 1- Stratigraphic relation of the formations and hydrogeological properties.

Geochronology			Lithostratigraphy		Lithology
Time	Period	Epoch	Formation	Symbol	Explanations
CENOZOIC	Quaternary		Alluvium	Qal	Sand, gravel, mud and block deposits.
			Slope debris	Qym	Blocks and gravel deposits on mountain slopes and skirts
	Tertiary	Pliocene Miocene	Çameli formation	Plç	Claystone, siltstone, marl, clayey limestone, sandstone, mudstone and conglomerate
MESOZOIC	Cretaceous	Late Cenoniyen	Kızılcadağ Ophiolitic Melange	Kkzm	Serpentinite, serpentinized harzburgite, dunite, radiolarite, chert, basic volcanite, neritic limestone, pelagic limestone, dolomite
		Liyas	Marmaris Peridotite Dunite Member	Kmo Kmod	Serpentinized ultramafic rocks, harzburgite, serpentinite, very olivine serpentinized dunites
			Iğdır Metamorphic	Kmoi	Amphibolite, amphibole schist, marble, quartzite, metabasalt
			Orhaniye formation	JKo	Basic volcanics, radiolarite, chert intermittent micrite
	Jura Triyas		Dutdere Limestone	TRJd	Few megaladon recrystallized limestones

3. Results and Discussions

3.1. Geology

The interaction time of groundwater with the lithological units control the chemical compound of the groundwater. Therefore, firstly the lithological units in the study area have been investigated. The lithological units are observed as Autochthonous and allochthonous units within the study area. Allochthonous units are composed from Marmaris Peridotite and Dunite Member, Kızılcadağ Ophiolitic Melange, Iğdır Metamorphites, Dutdere Limestones and Orhaniye formation. The autochthonous units are Alluvium and slope debris with Çameli formation (Şenel et al., 1989) (Table 1, Figure 2). The lithological formations in the study area have different hydrogeological properties. Alluvium which is the most important aquifer in the study area has an area of roughly 34.84 km^2. When the well logs are examined, it is seen that the thickness of alluvium is between 5 and 60 m in the study area.

3.2. Hydrochemistry

3.2.1. Seasonal Evaluation of Physical Parameters

The physical parameters of water samples were made in-situ for two seasons and the measurements (pH, EC, T (°C)) shown in table 2. The EC_{25} of groundwater samples in wet and dry season ranges from 296 to 1075 µs/cm and ranges from 279 to 1119 µs/cm, respectively. The EC_{25} of surface water samples in wet and dry season ranges from 532 to 2275 µs/cm and ranges from 759 to 2358 µs/cm, respectively. The temperature (°C) of groundwater samples in wet and dry season ranges from 11,5 to 21,4 °C and ranges from 8,5 to 16,1°C, respectively. The temperature (°C) of surface water samples in wet and dry season ranges from 17,7 to 23,5 °C and ranges from 14.6 to 15,6 °C, respectively. Temperature (°C) changes in surface water samples are related to climatic conditions. The pH of groundwater samples in wet and dry season ranges from 7,38 to 9,33 and ranges from 7,4 to 11, respectively. The pH of surface water samples in wet and dry season ranges from 8,39 to 9,08 and ranges from 8,02 to 8,62, respectively (Table 2). The pH values increased in wet season for water samples (Table 2). Generally, seasonally increase in physical parameters of water samples is related to the high interaction between rock and rainwater (Makwe and Chup, 2013; Ngabirano et al., 2016). Carbonates, bicarbonates, hydrooxides, phosphates, silicates and borates reduce the number of hydrogen ions (H^+) in water and the water gains basic character. The increase in hydrogen ion usually causes acidic water. There is a close relationship between HCO_3^- and CO_3^{2-} ions which are the main sources of alkalinity in water and H^+ ion concentrations in water. When the pH of the water exceeds 8,2, the bicarbonate ions are separated

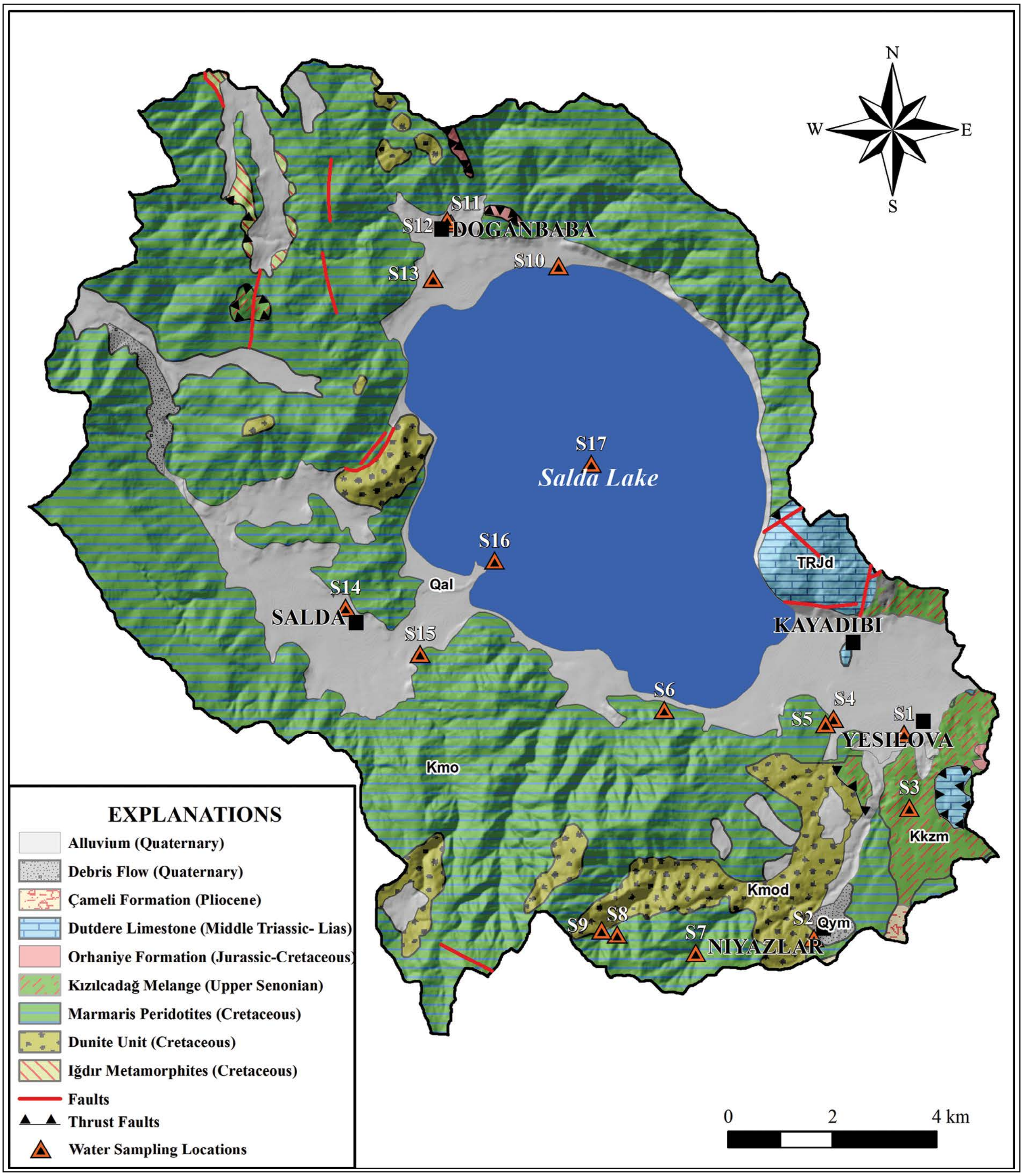

Figure 2- Geological map of the region [modified from Şenel et al. (1997).

into carbonate and hydrogen ions. In this condition, if the pH of the water is above 8,2, the CO_3^{2-} ions increase and if it is below this value, the HCO_3^- ion becomes the dominant ion. The presence of such a relationship is observed in the water samples in the study area. Electrical conductivity of water depends on the presence of ions in the water, total concentrations and temperature. The increase in temperature and ion concentration is proportional to the increase in electrical conductivity (Şahinci, 1991; Erguvanlı and Yüzer, 1987). Thus, due to the interaction of rock water, there is an increase in pH and EC values in groundwater and surface waters in the study area.

3.2.2. Seasonal Evaluation of Major Ions

The major chemical constituents of water samples were analyzed at two seasons (June 2015 and November 2015). In addition, the accuracy of major ion analysis results was evaluated with E.B (%).When the electrical balance results are examined, S1, S2, S5, S7, S14, S16 (for wet season), S10, S12, S13, S16 and S17 (for dry season) water samples have more than 5% error rate. Therefore, these samples have not been considered in chemical assessments. The results of the analysis are shown in table 2.

According to this, major carbonate rocks such as limestone and dolomitic limestone are the origin of Ca^{2+} and Mg^{2+} in water. The increase at Mg^{2+} in dry and wet seasons was observed at groundwaters discharged within the Kızılcadağ Ophiolite and Mélange. In the same way, Mg^{2+} increases in the surface waters associated with Kızılcadağ Ophiolite and Mélange. The major origin of Mg^{2+} in the groundwater and surface waters within the study area are ion exchange of minerals in rocks with water. The increase at K^+ which is another major ion was observed for both two seasons at S11. Likewise, this increase is related to ion exchange due to water-rock interaction.

HCO_3^- is the major anion component of the groundwater and surface waters. The HCO_3^- content of groundwater samples in wet and dry season range from 1,70 to 14,30 meq/L and 0,50 to 9,80 meq/L, respectively (Table 2). The major origin of HCO_3^- generally is due to the water- rock interaction and oxidation of organic matter. The Cl^- ion concentration at most of the samples in dry season increases related to water-rock interaction between rainwater with Kızılcadağ Ophiolite and Mélange in discharged waters from the contact of the Dutdere Limestone and Kızılcadağ Ophiolite and Mélange. The SO_4^{2-} originates from oxidation of sulphite (Ranjan et al., 2013). The SO_4^{2-} content of groundwater samples in wet and dry season range from 0,03 to 0,32 meq/L and 0,00 to 0,76 meq/L, respectively (Table 2). The SO_4^{2-} content of surface water in wet and dry season range from 0,06 to 0,34 meq/L and 0,10 to 0,35 meq/L, respectively (Table 2).

3.2.3. Hydrogeochemical Facies

Determination of hydrogeochemical facies it is important to determine the chemical background and origin of groundwater. It was developed by Piper (1944) to demonstrate the similarities and/or differences in the chemical properties of groundwater based on dominant cations and anions. Piper trilinear diagram were prepared for dry and wet seasons samples in the study area. According to the diagrams, the groundwater and stream water are “Mg^{2+}-CO_3^{2-}-HCO_3^-, Mg^{2+}-Ca^{2+}-CO_3^{2-}-HCO_3^- and Ca^{2+}-Mg^{2+}- HCO_3^- ” facies, and lake water is Mg^{2+}- CO_3^{2-}-HCO_3^- facies in the basin (Figure 3).

Table 2- Physical and chemical parameters of water samples.

Season	Sample No	Sample Type	pH	EC (µs/cm)	EC_{25} (µs/cm)	T (ºC)	Ca^{2+} meq/L	Mg^{2+} meq/L	Na^+ meq/L	K^+ meq/L	CO_3^- meq/L	HCO_3^- meq/L	Cl^- meq/L	SO_4^{2-} meq/L	Σ Cation meq/L	Σ Anion meq/L	Electrical Balance %
JUNE 2015 (WET SEASON)	**S1**	Well	7,58	543	689	13,9	3,16	5,43	0,62	0,02	0,00	6,80	0,49	0,77	9,23	8,06	**6,74**
	S2	Spring	8,43	459	559	15,6	0,86	7,61	0,14	0,00	1,60	5,80	0,08	0,08	8,61	7,55	**6,56**
	S3	Spring	7,38	427	542	13,9	3,21	3,16	0,76	0,01	0,00	6,10	0,24	0,32	7,13	6,66	3,46
	S4	Stream	8,57	517	532	23,5	0,72	7,13	0,14	0,01	2,00	5,10	0,11	0,06	8,00	7,27	4,79
	S5	Stream	8,39	704	735	22,8	1,27	9,78	0,24	0,01	1,80	7,80	0,15	0,08	11,30	9,83	**6,97**
	S6	Spring	9,13	467,3	597	13,6	0,13	10,01	0,10	0,01	4,20	4,90	0,09	0,09	10,25	9,28	4,95
	S7	Spring	8,27	506	585	17,9	0,41	8,51	0,10	0,01	1,00	6,60	0,06	0,05	9,04	7,72	**7,87**
	S8	Spring	8,36	346,1	393	18,8	0,46	5,11	0,10	0,00	1,40	3,80	0,06	0,05	5,68	5,31	3,32
	S9	Spring	9,05	275,9	296	21,4	0,14	4,33	0,06	0,01	2,60	1,70	0,04	0,03	4,53	4,38	1,69
	S10	Spring	7,81	845	1020	16	0,62	15,12	0,14	0,01	0,00	14,30	0,10	0,10	15,89	14,51	4,54
	S11	Spring	7,73	399,9	539	11,5	0,96	6,62	0,24	0,13	0,00	7,30	0,09	0,12	7,95	7,52	2,80
	S12	Well	8,15	707	874	15	0,52	12,69	0,22	0,01	0,60	10,60	0,24	0,20	13,44	11,63	7,21
	S13	Stream	8,39	546	634	17,7	0,89	8,72	0,18	0,02	1,40	7,50	0,08	0,07	9,81	9,05	3,98
	S14	Well	8,35	925	1075	17,7	0,26	3,85	1,02	0,08	3,40	0,20	0,68	0,01	5,20	4,30	**9,57**
	S15	Spring	9,33	312,7	369	17	0,11	5,63	0,05	0,01	3,60	1,70	0,05	0,04	5,80	5,40	3,62
	S16	Salda Lake	-	-	-	-	0,20	25,06	7,13	0,60	19,20	12,20	4,94	0,35	32,98	36,70	**-5,34**
	S17	Salda Lake	9,08	2066	2275	20,2	0,17	27,13	8,53	0,68	19,20	12,20	5,06	0,34	36,51	36,80	-0,39
NOVEMBER 2015 (DRY SEASON)	**S1**	Well	7,4	489,9	631	13,3	3,20	5,41	0,49	0,01	0,00	7,20	0,55	0,76	9,11	8,52	3,35
	S2	Spring	8,63	395,7	578	8,5	0,79	7,18	0,12	0,01	1,60	6,00	0,09	0,07	8,10	7,76	2,12
	S3	Spring	7,53	427,5	539	14,2	3,03	2,96	0,63	0,01	0,00	6,00	0,24	0,30	6,63	6,54	0,64
	S4	Stream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	S5	Stream	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	S6	Spring	9,31	422,1	557	12,3	0,09	8,54	0,08	0,01	4,40	4,20	0,10	0,09	8,72	8,79	-0,42
	S7	Spring	8,49	400,9	508	14	0,49	6,35	0,09	0,00	1,00	6,40	0,09	0,06	6,93	7,55	-4,29
	S8	Spring	8,57	294,9	372	14,2	0,41	4,60	0,08	0,00	1,20	3,40	0,07	0,05	5,09	4,72	3,79
	S9	Spring	9,25	219,7	279	13,9	0,14	3,62	0,05	0,00	2,20	1,90	0,05	0,04	3,81	4,19	-4,78
	S10	Spring	7,89	929	1119	16,1	0,65	16,18	0,14	0,01	0,00	15,00	0,12	0,04	16,99	15,17	**5,66**
	S11	Spring	7,95	618	760	15,2	1,06	9,25	0,27	0,15	0,00	9,80	0,23	0,14	10,72	10,17	2,68
	S12	Well	7,87	751	933	14,8	1,60	11,25	0,32	0,02	0,20	10,80	0,39	0,32	13,18	11,71	**5,90**
	S13	Stream	8,62	608	759	14,6	0,86	10,02	0,30	0,04	1,60	8,00	0,20	0,10	11,21	9,89	**6,26**
	S14	Well	9,84	247,4	307	14,9	0,13	2,41	0,87	0,04	2,40	0,50	0,81	0,00	3,44	3,71	-3,71
	S15	Spring	11	233,3	334	9,23	0,13	3,99	0,05	0,01	1,60	2,60	0,05	0,04	4,18	4,29	-1,37
	S16	Salda Lake	8,02	1912	2358	15,1	0,23	27,67	8,89	0,74	30,50	8,85	5,65	0,34	37,53	45,34	**-9,43**
	S17	Salda Lake	8,22	1921	2341	15,6	0,23	27,23	8,74	0,63	28,47	8,85	5,81	0,35	36,83	43,48	**-8,28**

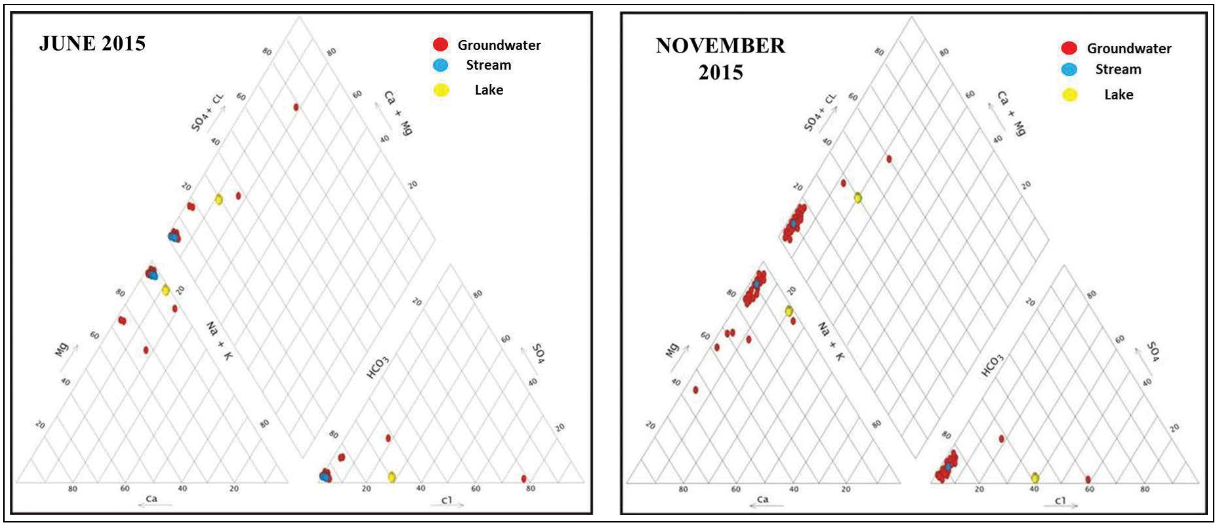

Figure 3- Piper diagrams prepared for dry and wet season (Piper, 1944).

3.3. Evaluation by Using the Stable Isotopes, Tritium and Radiocarbon of Water Samples

3.3.1. Evaluation the Stable Isotope (hydrogen and oxygen) Composition of Water Samples

The environmental isotopes of oxygen ($\delta^{18}O$), tritium ($\delta^{3}H$) and deuterium (δD) are excellent tracers for determining the origin of groundwater. The stable isotope analyses were made in wet and dry season in the Salda Lake basin. Table 3 contains data of isotopic compositions of groundwater and surface water.

The isotope compositions in water samples range from -10,24‰ to 0,30‰ $\delta^{18}O$ (wet season) and range from -10,08‰ to 1,86‰ $\delta^{18}O$ (dry season), respectively. The δD composition in water samples range from -64,51‰ to -2,80‰ (wet season) and range from -69,14‰ to 0,02‰ (dry season), respectively (Table 3).

The relationship between the $\delta^{18}O$ and δD values of water samples is plotted in figure 4. In this graphic is shown the Global Meteoric Water Line ($\delta D = 8\delta^{18}O + 10$) with d-excess value of 10‰ (Craig, 1961) and the Meteoric Water Line of Lake District in Turkey ($\delta D = 8\delta^{18}O + 14{,}6$) with d-excess value of 14.6‰ (Dilsiz, 2006).

According to the diagram (June 2015 in figure 4) large part of the water samples (S2, S4, S5, S6, S7, S16, S8, S10, S11, S12, S13, S14, S15) are located around the Global Meteoric Water Line ($\delta D = 8 * \delta^{18}O + 10$) and in addition S9 is in regions near the Lake Region Meteoric Water Line (Figure 4). This situation proves that the groundwater and surface waters in the study area are meteoric origin. The location of the S3 spring water deviates from the GMWL line to the right in June 2015. This indicates that water-rock interaction is dominant in S3. In addition, evaporation was observed to be dominant in S16 and S17 samples taken from Salda Lake during this period.

According to the diagram (November 2015 in figure 4) large part of the water samples (S2, S6, S7, S8, S9, S10, S11, S12, S13, S14 and S15) are located around the Global Meteoric Water Line ($\delta D = 8 * \delta^{18}O + 10$). This situation proves to be meteoric origin of groundwater and surface waters in the study area as in June 2015. Besides, it was determined that water rock interaction was more dominant especially in S1, S3, S4 and S5 samples compared to Nov 2015 and June 2015. In addition, evaporation was observed in S16 and S17 samples taken from Salda Lake during this period. In addition, evaporation was dominant in S16 and S17 samples taken from Salda Lake during this period (Figure 4).

3.3.2. Evaluation the D-Excess Values of Water Samples

Another evidence for the origin of recharge of groundwater within the study area is obtained from the value of the deuterium excess (d-excess). Locally, d-excess values due to differences in meteorological state at the source region of the vapour mass vary

Table 3- Isotopic composition of groundwater.

Season	Sample No	Sample Type	$d^{18}O$	δD	d-excess* (‰)	^{3}H (TU)	$d^{13}C$ ‰	^{14}C (year)
JUNE 2015 (WET SEASON)	**S1**	Well	-8,90	-60,01	11,19	-	-	-
	S2	Spring	-9,28	-59,77	14,47	3,28	-15,6	530
	S3	Spring	-7,69	-55,91	5,61	1,91	-	-
	S4	Stream	-8,10	-54,28	10,52	3,07	-14,4	700
	S5	Stream	-8,14	-56,30	8,82	2,66	-	-
	S6	Spring	-9,21	-63,03	10,65	2,48	-16,3	5820
	S7	Spring	-9,68	-63,34	14,10	3,16	-16,6	2130
	S8	Spring	-9,80	-61,86	16,54	-	-16,5	2260
	S9	Spring	-10,24	-64,51	17,41	3,71	-16,0	5990
	S10	Spring	-8,74	-57,60	12,32	-	-15,8	1020
	S11	Spring	-8,80	-58,16	12,24	3,18	-	-
	S12	Well	-8,62	-56,54	12,42	-	-	-
	S13	Stream	-8,23	-53,75	12,09	-	-	-
	S14	Well	-8,50	-57,58	10,42	-	-	-
	S15	Spring	-9,74	-62,10	15,82	-	-	-
	S16	Salda Lake	-1,41	-12,54	-1,26	-	-0,8	110
	S17	Salda Lake	0,30	-2,80	-5,20	4,18	-0,7	90
NOVEMBER 2015 (DRY SEASON)	**S1**	Well	-8,58	-61,04	7,60	2,53	-	-
	S2	Spring	-9,23	-66,04	7,80	2,97	-	-
	S3	Spring	-7,55	-59,23	1,17	1,74	-	-
	S4	Stream	-7,89	-52,81	10,31	3,01		
	S5	Stream	-7,77	-51,47	10,69	2,45		
	S6	Spring	-9,33	-64,54	10,10	2,34	-	-
	S7	Spring	-9,51	-64,18	11,90	3,12	-	-
	S8	Spring	-9,94	-67,42	12,10	3,04	-	-
	S9	Spring	-10,08	-69,14	11,50	3,67		
	S10	Spring	-9,05	-61,29	11,11	3,42	-	-
	S11	Spring	-8,87	-59,04	11,92	3,38		
	S12	Well	-8,99	-60,71	11,21	3,35	-	-
	S13	Stream	-8,56	-58,76	9,72	-	-	-
	S14	Well	-8,52	-57,39	10,77	1,04	-	-
	S15	Spring	-9,91	-63,55	15,73	2,77	-	-
	S16	Salda Lake	1,86	0,02	-14,86	4,02	-	-
	S17	Salda Lake	1,75	-1,68	-15,68	4,27	-	-

* *d-excess = δD - 8δ^{18}O (Dansgaard 1964)*

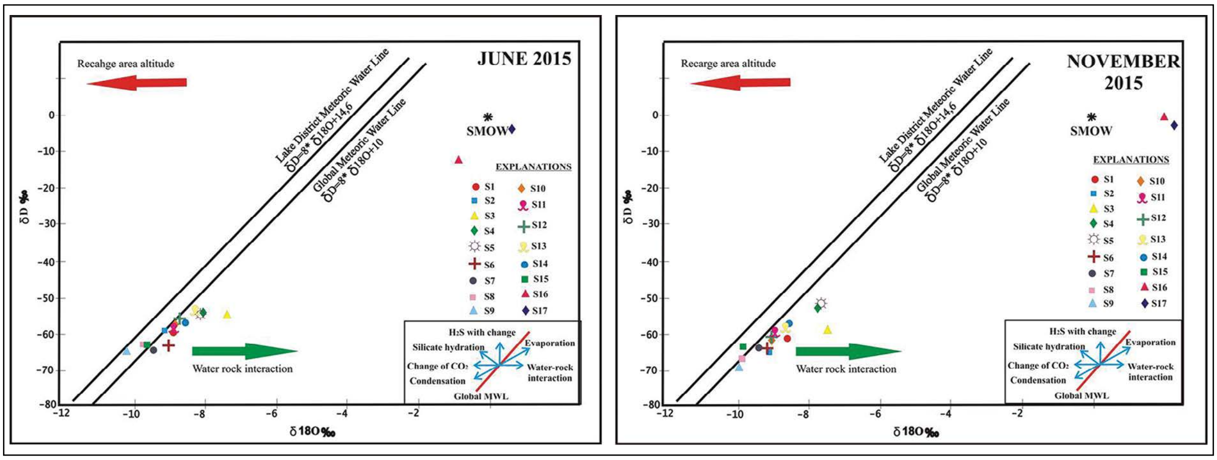

Figure 4- Graphic of δD and δ^{18}O for Salda Lake basin water samples in wet and dry season (June and November 2015).

(Merlivat and Jouzel 1979). The d-excess values are defined by the following equation (Dansgaard 1964);

$$\text{d-excess} = \delta D - 8\delta^{18}O \qquad [2]$$

The d-excess values for the water samples in the study area varied from -5,2 to 17,41‰ and from -16,44 to 15,73‰ for wet and dry seasons, respectively (Table 3).

According to the results of the analysis, samples of S3, S5, S16 and S17 are lower than 10 and other waters are higher than 10 in wet seasons (June 2015). In dry seasons (November 2015), the samples with the numbers of S1, S2, S3, S13, S16 and S17 are lower than 10 while the other waters are higher than 10. According to this, waters with excess deuterium values of more than 10, atmospheric and marine origin precipitation waters with high velocity evaporation effect of the regions; Waters with values lower than 10 are originating from terrestrial rainfall under the influence of evaporation.

3.3.3. Evaluation the Tritium Values of Water Samples

$\delta^{18}O$-^3H relation; tritium is produced in the upper atmosphere. Tritium is a short-lived isotope of hydrogen with a half-life of 12,43 years. The tritium in groundwater indicates that the aquifer is being recharged with water that originated before or after 1950s (Schlosser et al., 1988; Busenberg and Plummer, 1993; Aggarwal et al., 2000). Activity of geogenic ^{3}H in most groundwater is negligible. Thus measurable ^{3}H in groundwater samples virtually always signifies modern recharge (Clark and Fritz, 1997).

The tritium concentrations in the groundwater and surface water samples are very low and ranging from 1,91 to 4,18 TU (wet season) and from 1,04 to 4,27 TU (dry season), respectively (Table 3). The diagram of tritium values versus δ^{18}O of water samples is shown figure 5. According to the results of the analysis (S2, S7 and S9) is recharge from higher elevations than the other samples in wet seasons at the study area. In addition, S8, S9, and S15 are recharge from higher elevations than the other samples in dry seasons. Also, S3 spring water in wet season is the deepest and the longest stay in the underground. In dry season same way, S3 and S14 waters are the deepest and the longest stay in the underground.

d^2H - ^3H relation; tritium, one of the radioactive

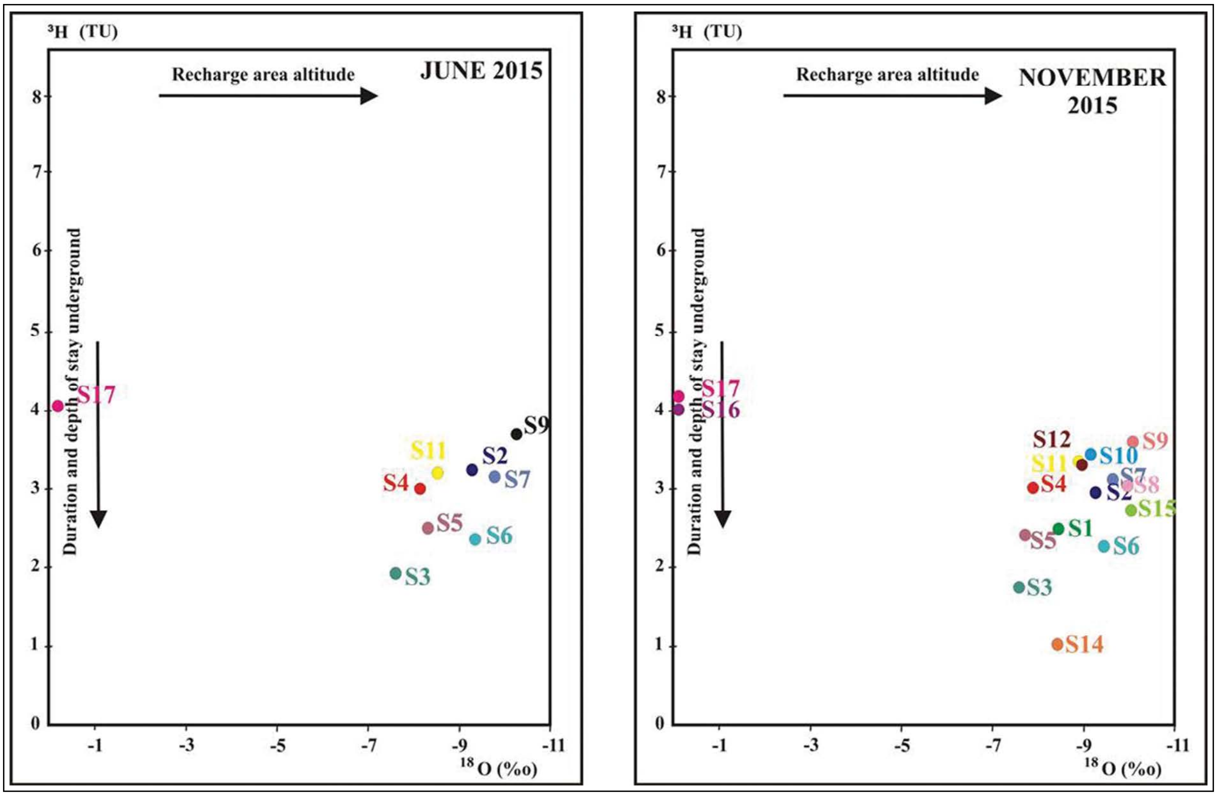

Figure 5- ^{3}H - δ^{18}O graphic (June and November 2015).

isotopes, undergoes continuous decay through natural half-life. Accordingly, if the content of tritium in the rainfall that supplies the groundwater is known, can be suggested ideas about determining the weighted average age of the groundwater or mixing conditions of different groundwater. The d^{2}H - ^{3}H chart reflects the relationship between recharge elevations in water and the duration of stay in the aquifer. In this graph, the recharge area elevation in the initial direction of the horizontal axis (d^{2}H) and the continuation of the aquifer in the initial direction of the vertical axis (^{3}H) are increasing (Afşin et al., 2007). Figures prepared with d^{2}H and ^{3}H values of the samples taken in June 2015 and November 2015 periods in the study area are presented in figure 6. According to ^{3}H values, in the wet season (June 2015), S9 has the youngest, shallowest and fastest circulating water feature. S3 is the oldest, deepest and slowest circulating water in the same period. Other water samples represent shallow and medium circulating waters with mixing and transitional water characteristics. According to the results of the dry season (November 2015) analysis, the water with the deepest and slowest circulation in the samples is taken from the well of S14. In the same period, the spring (S10) is the shallowest and fastest circulating groundwater. Lake water samples (S16, S17) represent shallow and medium circulating waters in the mixture and transitional waters.

EC_{25} - ^{3}H relation; the isotope of tritium (^{3}H), which is used for isotopic evaluation of water, is radioactive in proportion to the residence time of groundwater in the reservoir. Therefore, ^{3}H isotope is one of the most important parameters in determining the relative ages of groundwater. Similarly, the EC value of the samples also increases due to the residence time of the groundwater in the reservoir (Guner and Guner, 2002).

In periods (June (S17), November (S16, S17)), the high tritium and low EC_{25} values of the samples taken from the Salda Lake indicate that the transition times of these waters are short. S4, S5 and S7 samples in June 2015 and S10, S12 samples in November 2105 have low tritium and high EC_{25} values show that these spring waters are deeply circulated (Figure 7). Also, S2, S3, S6, S9 and S11 (June-2015) and S1, S2, S3, S6, S7, S8, S9, S11, S14 and S15 (Nov-2015) samples have low EC_{25} value and tritium content. This shows that the samples are deeply circulated.

3.3.4. Evaluation the Radiogenic Isotope Values of Water Samples

The main sources of the carbon element in the groundwater are (i) atmospheric CO_2, (ii) organic CO_2 resulting from the organic activities in the infiltration zone, (iii) geogenic CO_2, and (iv) carbonate (CO_3) ions that are absorbed by the dissolution of carbonate minerals. The main sources of geogenic CO_2 are metamorphism of carbonate rocks and ground-mantle CO_2 escape. Atmospheric and biogenic CO_2 contains ^{14}C, whereas geogenic and dissolved CO_2 do not contain ^{14}C at all. The carbon element provided by CO_2 sources in the groundwater is called Total Dissolved Inorganic Carbon (TDIC). ^{14}C age determination studies of groundwater are mostly used with ^{14}C origin of TDIC, and age determination based on dissolved organic carbon content is also possible (Bayarı et al., 2005). The ^{14}C activities of the samples vary between 90 pmc to 110 pmc for Salda Lake waters and 530 pmc to 5990 pmc for the groundwater. ^{13}C values were

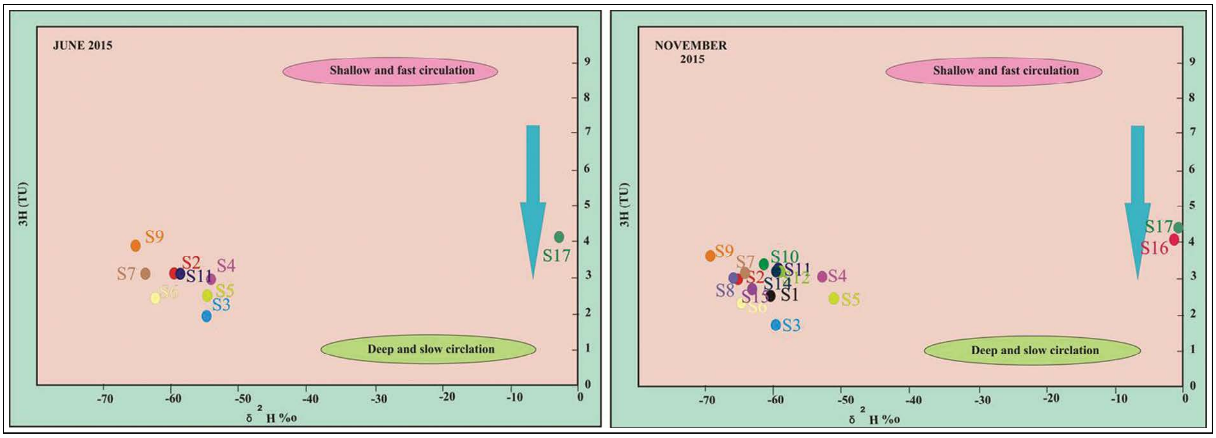

Figure 6- d^{2}H -^{3}H graphic (June and November 2015).

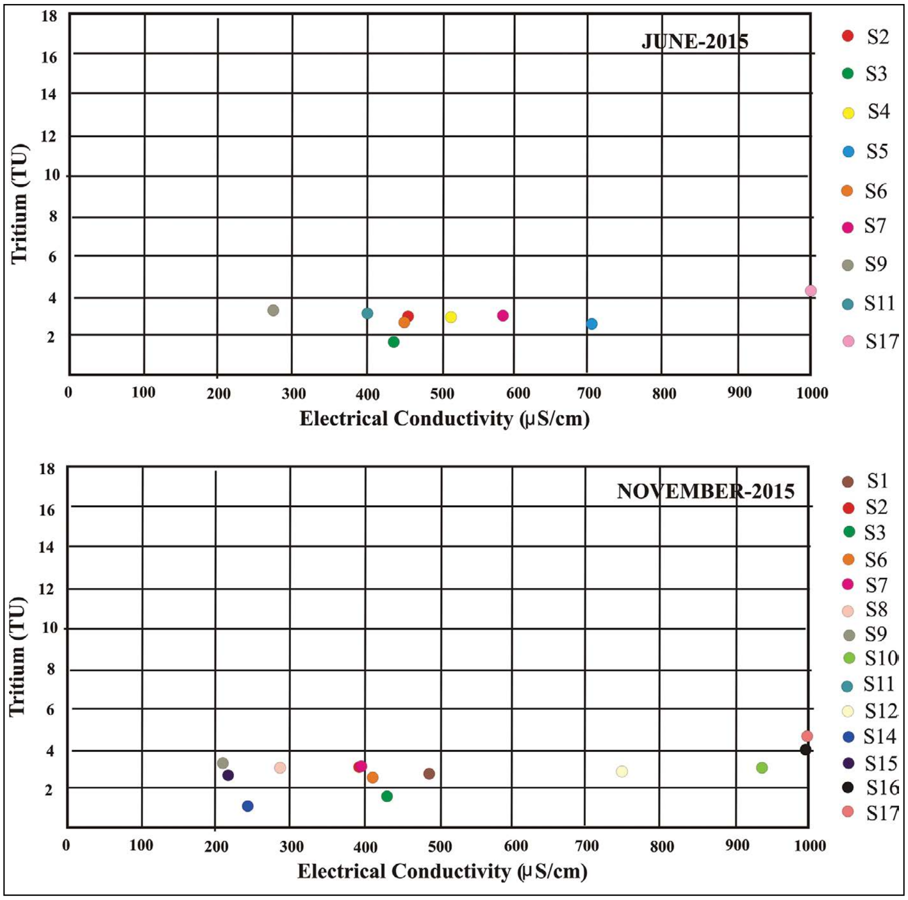

Figure 7- EC$_{25}$ -^{3}H graphic (June and November 2015).

-15,6 to -16,6 in spring waters and -0,8 and -0,7 in lake waters (Table 3). According to this, CO$_2$ is the solution of marine limestone and fresh water carbonates in the lake waters, while in the groundwater it is geogenic (dissolved and mantle in the groundwater) (Figure 8)

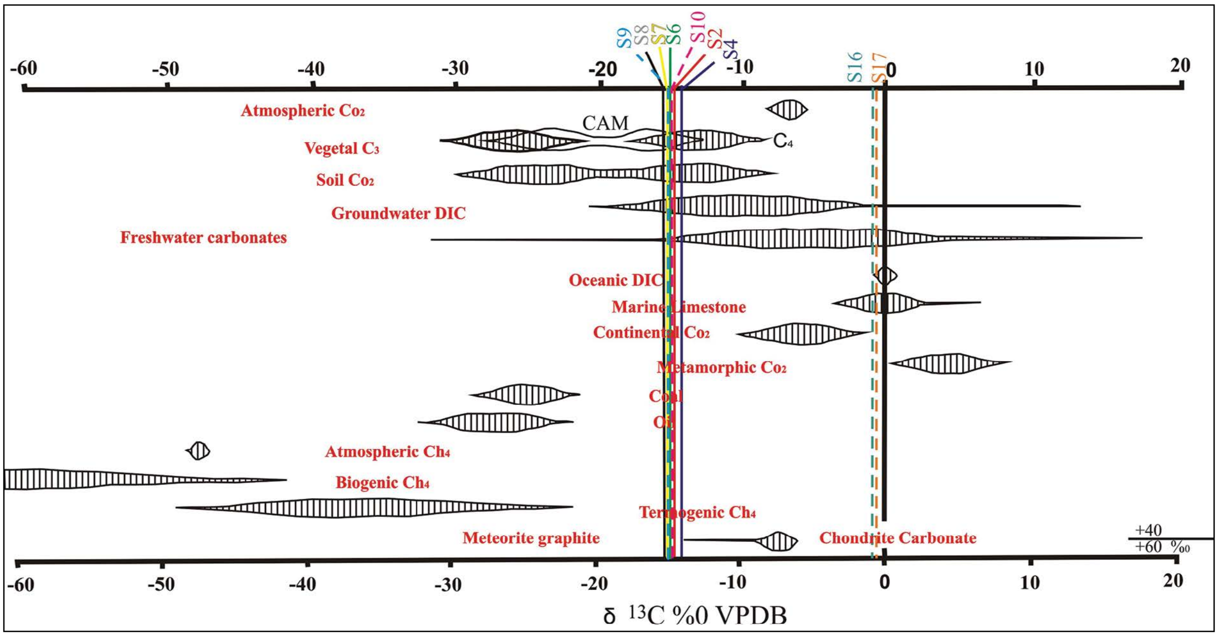

Figure 8- According to Clark and Fritz (1997), in terms of the origin of natural carbon compounds of ^{13}C values of investigated waters.

4. Conclusions

This study used water chemistry and isotope data to investigate origin, recharge processes (the recharge area, circulation depth) of groundwater and surface water in the Salda Lake basin. The groundwater chemical composition was "Mg^{2+}-CO_3^{2-}-HCO_3^-, Mg^{2+}-Ca^{2+}-CO_3^{2-}-HCO_3^- and Ca^{2+}-Mg^{2+}-HCO_3^-" facies. The lake water was Mg^{2+}-CO_3^{2-}-HCO_3^- facies in the basin. All the groundwater and surface water system is recharged by meteoric precipitation. Groundwaters in the study area are recharged from high elevations and lake waters are recharged from low elevations in the basin. According to this, waters with excess deuterium values of more than 10, atmospheric and marine origin precipitation waters with high velocity evaporation effect of the regions; waters with values lower than 10 are considered to be waters originating from terrestrial rainfall under the influence of evaporation. According to the tritium analysis results, S3 and S14 in the study area are recharge from higher elevations than the other samples in both seasons. In addition, according to radiogenic isotope, CO_2 is the solution of marine limestone and fresh water carbonates in the lake waters, while in the groundwater it is geogenic.

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