-Short Communication-

Weight-Frequency Percentage ($\%W_F$) of ionic composition of Urmia Lake in last 156-year (1852-2008)

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Abstract

Although the study of physicochemical characterization of Urmia Lake confirms the salinity of lake is changing but this study has focused on the pattern of Weight-Frequency Percentage ($\%W_F$) form 1852 to 2008. Reanalysis of last data showed $\%W_F$ hasn't had homogenous structure of Weight-Frequency Percentage in Urmia Lake during the period 1852-2008 (Eimanifar and Mohebbi, 2007).

Urmia Lake is one of the most valuable ecosystems in the world. Despite the high salinity of the lake, it is the host of unique species of brine shrimp; *Artemia urmiana* Günther, 1899 and several genera of algae have been reported from Urmia Lake. Also it is the permanent or temporary habitat for a significant number of birds. Its islands, marshes and lagoons are natural environments for a large number of plants species.

Although Urmia Lake currently is undergoing an environmental crisis in terms of water loss several studies also show that Urmia Lake has always been subject to large changes including seasonal drought as well as heavy rain, conditions that can be dominant, depending on the year. Figure 1 shows the surface level of lake fluctuations from 1965 to 2010. This diagram shows that Urmia Lake experienced a drought during the period 1965-1968. The water level during this period matched that of 2003-2004 with an average salinity of more than 280 $g.l^{-1}$ (Asem *et al*. 2010).

Historical formal and informal documents have indicated that Urmia Lake experienced a severe drought in 1800, more that 200 years ago. Its maximum depth was only 75 cm and a road had been created across the lake from west to east enabling native traversing. Tales from elders confirm the presence of this road (Tamaddon 1971). This record shows that Urmia Lake has undergone more extreme droughts than present conditions and also that the lake recovered its volume during each climate cycle. Therefore, salinity and ionic composition changes aren't unexpected over time.

But there is very important limnological issue here: have Weight-Frequency Percentage ($\%W_F$) of the ionic composition of Urmia Lake changed over time, with different ecological and environmental consequences, or is that not the case? An aim of this paper is to answer this question with regards to the 156-year hydro-chemical information available about Urmia Lake.

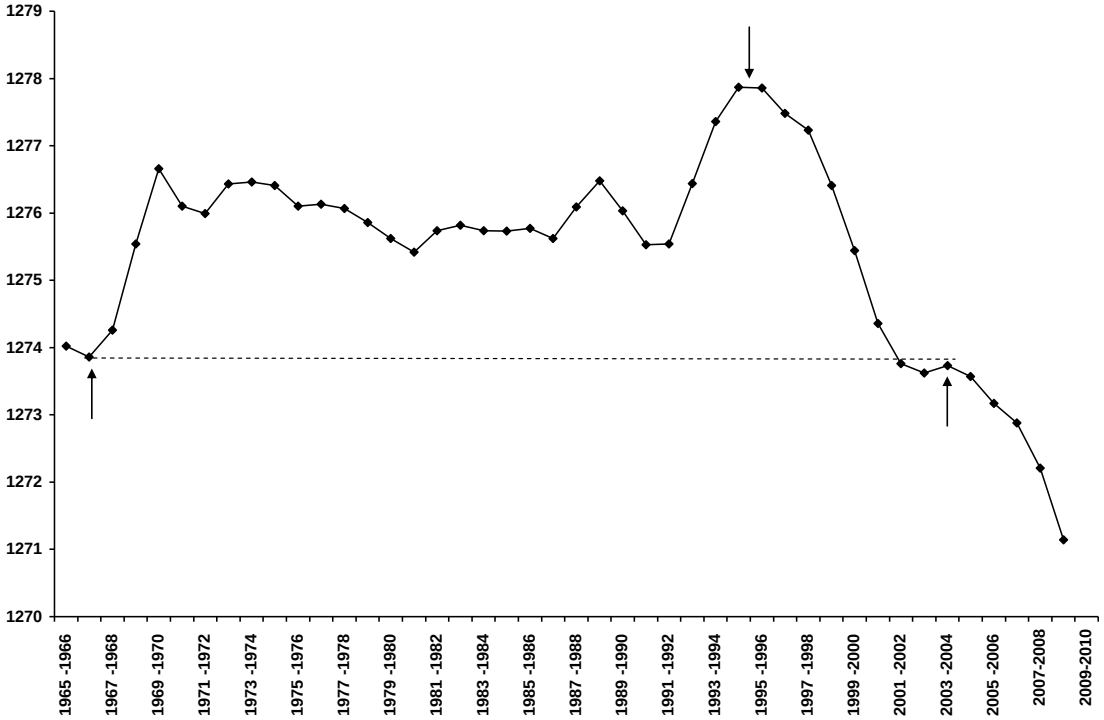

Fig. 1: Water level fluctuation of Urmia Lake (1965-2010)

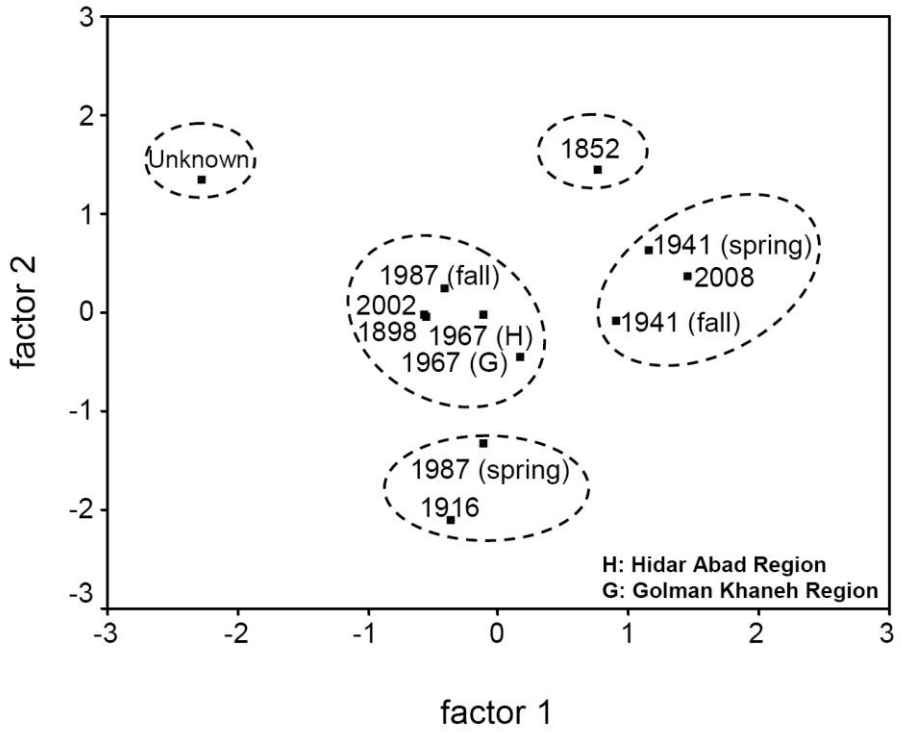

Fig. 2: Biplot diagram PCA to dispersion with Weight-Frequency Percentage (%W_F) of the ionic composition of Urmia Lake from 1852 to 2008

Hydro-chemical data and information were collected from 1852 to 2008 (See Asem and Mahmoudi, 2013):

- ✓ Abich, 1856
- ✓ Hunt, 1868
- ✓ Günther and Manley, 1898
- ✓ Khlopin, 1923
- ✓ Adarangi, 1941
- ✓ Djonidi, 1970
- ✓ Daneshvarand Ashasi Sorkhabi, 1997
- ✓ Jamshidi, 2002
- ✓ Karbassi *et al*., 2010

Information about total salt and Weight-Frequency Percentages ($\%W_F$) of ionic composition was obtained from each of these references.
Finally, principle components analysis (PCA) has been used for grouping and classification of different years according to the differences and similarities of Weight-Frequency Percentages ($\%W_F$) of ionic composition during the last 156-years. Statistical analysis had been done with SPSS.
Table 1 shows Weight-Frequency Percentage ($\%W_F$) of seven inorganic ions in Urmia Lake over a 156-year period. Maximum and minimum of $\%W_F$ and its changes are given in Table 2.
With regards to results (Table. 2) the minimum changes of $\%W_F$ belong to Cl^- and Na^+ with 1.05 (5.11%) and 1.11 (11.35%) respectively. The maximum changes of $\%W_F$ are found in Br^- which increased about 4 times (300%) over a twenty-year period, from 1967 to 1987.
About other ions, the change of $\%W_F$ for K^+ is 1.41 (41.81%), Ca^{2+} is 3.8 (280%), Mg^{2+} is 2.18 (118%) and $SO_4^=$ is 1.58 (57.9%) (See Table 2). A biplot diagram of PCA shows the dispersion and grouping according to Weight-Frequency Percentage ($\%W_F$) of the ionic composition of Urmia Lake from 1852 to 2008 (Fig 2).
With regards to PCA results, a 156-year period of Urmia Lake is grouped by five separate categories in Figure 2:
Group 1: Unknown
Group 2: 1852
Group 3: spring and fall 1941 and 2008
Group 4: 1967 (Heydar Abad region), 1967 (Golman Khaneh region), spring1987, 2002, 1898
Group 5: 1932, fall 1987

In PCA, the first and second components show 47.04% and 26.35% of the total variation respectively; in total the two components show 73.39% of variation. In the first component, Mg^{2+} and $SO_4^=$ are the most important in grouping.
Overall, the study of these results over a 156-year period, shows that the $\%W_F$ of Cl^- and Na^+ have a stable profile (especially Cl^-). However, with respect to the $\%W_F$ of other ions, there are significant changes between maximum and minimum amounts for K^+, Ca^{2+}, Mg^{2+}, $SO_4^=$ and especially Br^- over the last 156-years. We can't provide a definitive assessment about Ca^{2+} because this ion can deposit with $CO_3^=$ at high temperatures and be removed from solution.
The 300% change (about 4 fold) for $\%W_F$ of Br^- over a twenty-year period (1967-1987) is noteworthy. Unfortunately the last report of Br^- is for 1987 and has not been evaluated in other hydro-chemical studies of Urmia Lake.

Table 1: Weight-Frequency Percentage (%W_F) of ions in 1852 to 2008

Data of sampling	Salinity ($g.l^{-1}$)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	$SO_4^=$	Br^-	Ref.	Study Area
1852	205.50	36.47	-	0.26	1.44	58.11	3.73	-	Abich	unknown
unknown	222.80	33.96	-	0.10	3.00	57.53	5.09	-	Hunt	unknown
Sept. 1898	164.83	33.97	0.78	0.31	2.54	57.33	4.21	-	Günther and Manley	Kaboudan Island
1916	188.40	33.41	0.68	0.38	2.09	55.28	4.81	-	Khlopin	Qushchi Cost[1]
1941 (spring)	261.11	33.54	-	0.17	3.14	57.06	5.67	-	Adarangi	Sharaf Khaneh region
1941 (Fall)	284.79	33.39	-	0.28	3.13	57.03	5.64	-		
July 1967	288.16	34.70	0.62	0.26	2.62	56.54	4.97	0.02	Djonidi	Heydar Abad region
	282.12	33.26	0.64	0.28	2.65	56.74	4.76	0.02		Golman Khaneh region
May 1987	235	33.51	0.55	0.31	2.45	55.66	4.60	0.08	Daneshvar and	Average of 29 stations[2]
Oct. 1987	251	34.27	0.56	0.27	2.47	57.25	4.53	0.08	Ashassi	Average of 90 stations[3]
2002 (Spring)	212	34.13	0.64	0.35	2.36	57.63	4.73	-	Jamshidi	Rashakan region
Jun 2008	380	32.75	0.69	0.15	2.97	56.90	5.89	-	Karbassi *et al*.	Ave. of 48 stations

1) see also: Petrov Mikhail Platonovich (1955); 2) in North part of lake 3) Whole of lake

Table 2: Max. and Min. of Weight-Frequency Percentage (%W_F) and amount of change

	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	$So_4^=$	Br^-
Max (year)	36.47 (1868)	0.78 (1898)	0.38 (1916)	3.14 (1941)	58.11 (1868)	5.89 (2008)	0.08 (1987)
Min (year)	32.75 (2008)	0.55 (1987)	0.1 (1852)	1.44 (1868)	55.28 (1916)	3.73 (1868)	0.02 (1967)
Changes	1.11	1.41	3.8	2.18	1.05	1.58	4
%Changes	11.35%	41.8%1	280%	118%	5.11%	57.90%	300%

With regards to $\%W_F$ of ions and the results of PCA:
I) $\%W_F$ has changed regardless of salinity and weight of ions ($g.l^{-1}$)
II) hydro-chemical structure of Urmia Lake grouped in five categories during the last 156-years from 1852 to 2008.
III) Urmia Lake had a similar hydro-chemical structure of $\%W_F$ ions in spring and fall 1941 and 2008. Also, its structure had a similar profile in 1898, 2002, 1967 and fall 1987. Other identical groups belong to 1916 and spring1987. It is significant that spring and fall of 1987 grouped in two different categories (see Fig. 2).
In conclusion, $\%W_F$ hasn't had homogenous structure in Urmia Lake during the period 1852-2008; but principle components analysis (PCA) proves that in some years it has had the similarly conditions with Weight-Frequency Percentage of ionic composition.

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