IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Chemical analysis of lake water quality

To cite this article: Yiqun He 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **632** 022043

Chemical analysis of lake water quality

Yiqun He*

College of Environment, Hohai University, Nanjing, Jiangsu, China

*Corresponding author email: yiqunhe@hhu.edu.cn

Abstract. Mono Lake is a large salt lake located in the Great Basin of North America. With the change of climatic conditions and diversion scheme, the inflow of fresh water also varies greatly, which makes the content of anionic cation in Mono Lake also changes. We detect the change of material concentration and anion content in Mono Lake by the change of geographical position and water level of Mono Lake. We also compared the content of anions and cations in average spring water and average stream water. Find out the characteristics of the ion content in Mono Lake and try to speculate the reasons. Through the analysis of the relationship between different anions and cations, PH concentration factor and molarity change in ordinary water, and the inference of the cause of their change, the changes of anions and cations composition in mono Lake Water with the change of water level were detected.

Keywords: Mono Lake, Chemistry, PH Concentration Factor, Anions and Cations.

1. Introduction

Mono Lake (Fig.1), located in eastern California, is the second largest Lake in the state of California. It is one of the oldest lakes in North America. Its water has no outlet but depends on evaporation. As a result, it leaves behind a lot of salt deposits with a salinity more than twice that of ordinary ocean water.

Mono Lake is one of the oldest lakes in North America, with a history of 760,000 years. Five rivers from the snow-capped mountains flowed into the lake, but there was no outlet. The water accumulated in the lake and slowly evaporated, leaving the salt in the water. So this kind of lake where the water doesn't get out is like a little ocean, and it's bound to be a saltwater lake [1]. Mono Lake has an extremely high salt concentration, almost three times that of sea water. Mono Lake water is also highly alkaline, with a pH of up to 10, while the sea water has a pH of only 8. Part of mono Lake's water comes from underground. The underground spring is rich in calcium and the river is rich in carbonic acid. The combination of the two forms calcium carbonate, which slowly precipitates and crystallizes in the spring at the bottom of the lake, forming travertine. In 1941, Los Angeles, more than 500 kilometers away, diverted water from the river into Mono Lake to provide drinking water to the public. As a result, the water level of Mono Lake gradually dropped by more than 10 meters, and the strange travertines came out of the water, forming a dream-like world. It is also a vibrant world, home to millions of water birds of dozens of species. But no fish can survive in water so alkaline and salty. Waterbirds feed on brine worms and water flies, both endemic to Mono Lake. Halogen worms and water flies also feed on algae, forming a complete food chain.

Hydrologically closed lakes respond rapidly to environmental changes, and typically carry extensive sedimentary records, making them excellent targets for studies of climate change (Broecker et al., 1998;

Lin et al., 1998) [2]. Chemical variations in sediments from closed lakes of the western U.S. Great Basin appear to mirror, for example, climate variability in the north Atlantic through the Holocene (Bischoff et al., 1997; Benson et al., 1998). Examination of stable isotope systems of major elements such as O and C in lacustrine sediments can yield direct information about environmental changes, alkalinity and hydrologic balance (Stuiver, 1970; Talbot, 1990; Li and Ku, 1997). It is important to consider additional proxies in order to provide both greater detail in pale environmental studies and to be able to examine other pale compositional parameters [3].

By analyzing the ratio of anions and cations in the water in different regions, we tried to explore the chemical composition of Mono Lake. Major changes in chemical composition, due to continuous evaporation of mono Lake water, fresh water flowing into Mono Lake again, and some biological effects of mono Lake water chemical composition is also constantly changing.

2. The Mono Basin

Mono Lake (Fig. 1) is ideal for this type of study by virtue of its long lifetime (3 Ma, hydrologically closed for 1 Ma; Phillips et al., 1995), simple hydrological budget, and the wealth of previous studies on aspects of its chemistry (Oxburgh et al., 1991; Connell and Dreiss, 1995; Neumann and Dreiss, 1995), hydrology (Blevins et al., 1984; Connell and Dreiss, 1995; Rogers and Dreiss, 1995), and sedimentology (Stine, 1990; Newton, 1994). Quaternary felsic to mafific volcanic rocks are cardinal sources of alluvium that dominates the Mono Basin. Creeks drain primarily Mesozoic arc-related granitic rocks of the Sierra Nevada (Fig. 1) [4]. The major anion content of Mono Lake is divided almost evenly between chloride, sulfate, and bicarbonate (Blevins et al., 1984). Its high pH and alkalinity leads to high concentrations of elements that ordinarily have short residence times in lakes (e.g., lanthanides, Johannesson and Lyons; 1994; actinides, Simpson et al., 1982). Calcium carbonate precipitates spontaneously from the lake where springs enter, forming the spectacular tufa towers (Jehl, 1983).

The highest water level in Mono Lake was 2,155 meters, and the current water level in Mono Lake is about 1,946 meters. For the last 4,000 years, the highest water level was 1,980 meters.

As a result, we can see the marks left by the rising water in Mono Lake. To the east of Mono Lake is a lot of glacial melt water, which is part of mono Lake's fresh water supply. As a result, in the east and southeast of Mono Lake there are many small streams and valleys feeding fresh water.

Mono Lake's main sources of water include melt water and spring water from streams that rain in the eastern Sierra Nevada Mountains. Direct precipitation over lakes is only a small part of the hydrological budget. There are two islands in the middle of Mono Lake, both formed by volcanic eruptions. Some craters in the northeast are getting older and older from far to near. The closest one is about 3,000 years old.

Because the water level of Mono Lake is constantly changing, so is the concentration of mono Lake (Fig.2). And we can see that in 1982, mono Lake reached its lowest level ever, when its salt content reached 100 grams per liter. The water in Mono Lake is about three times as salty as sea water. The higher the lake level, the lower the salt concentration has a strong trend, but it can only get as low as 0 and then stay there.

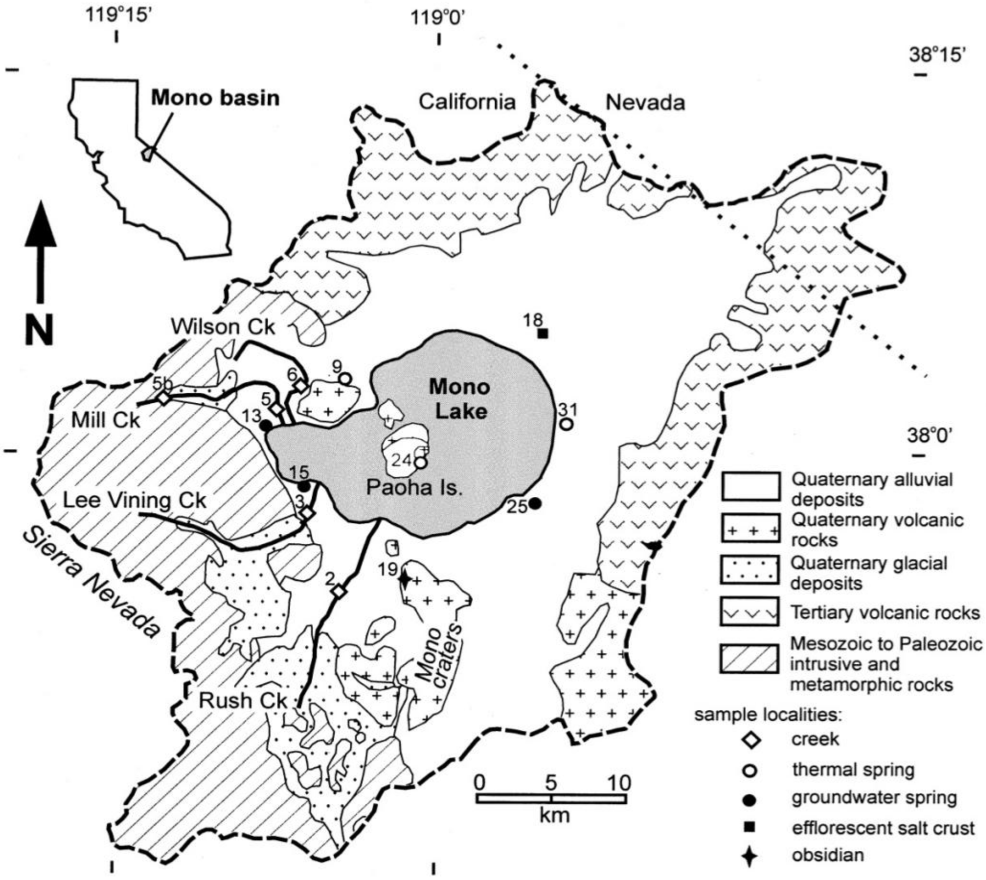

Figure 1. Simplified geology of the Mono Basin (modified from Blevins et al., 1984). Sample locations are noted with the last 1–2 digits of the full sample number used in the tables (e.g., sample location "24" is the collection site for sample MONO 99f-24).

Because the water level of Mono Lake is constantly changing, so is the concentration of mono Lake (Fig.2). And we can see that in 1982, mono Lake reached its lowest level ever, when its salt content reached 100 grams per liter. The water in Mono Lake is about three times as salty as sea water. The higher the lake level, the lower the salt concentration has a strong trend, but it can only get as low as 0 and then stay there.

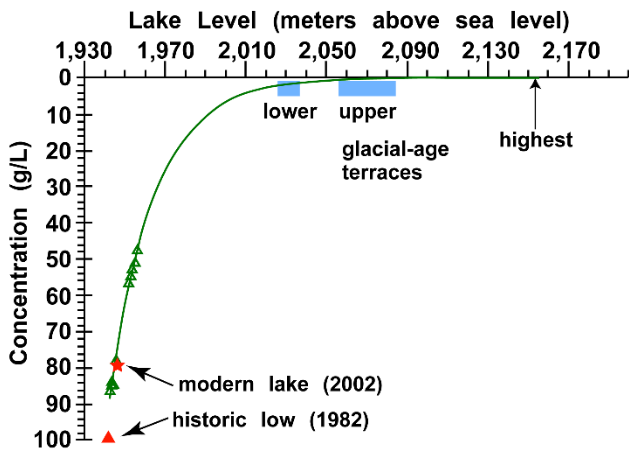

Figure 2. Connection between the lake level and salt content of mono lake

3. Concentrations of cations and anions

The counterparts of cations and anions (Fig.3) are different between the water in mono lake and in spring water or creek water. We can see that mono Lake has a very high sodium content, more than half. The carbonate, sulfate, and chloride ions in Mono Lake water are about the same. Natural water is organized or classified according to the concentration of ions. So mono Lake has roughly equal concentrations of sulfate and chloride ions. Other elements like calcium, magnesium and potassium are very small. And we know that the water in Mono Lake is very salty. And then it's this mixed anion composition. In the average spring water, there's actually kind of a high concentration of carbonate. And that's the reason that mono lake has high carbonate. We can see that this the stream, the creeks have also hired carbonate, but it's roughly equal carbonate sulfate, chlorine. Sulfate and chlorine are really kind of low upon it’s in the spring waters. Sodium is also the biggest element in the spring waters as well. That's partly because at some level, the spring waters are actually mixing with the lake water as well. The average creek has a much more sort of even distribution of the elements. So calcium is actually more abundant than sodium. And magnesium is even more abundant than soviet. Then the the cation distribution in the creek water also it's quite different than the cation distribution in the lake water. That's because of the processes that take place in the lake.

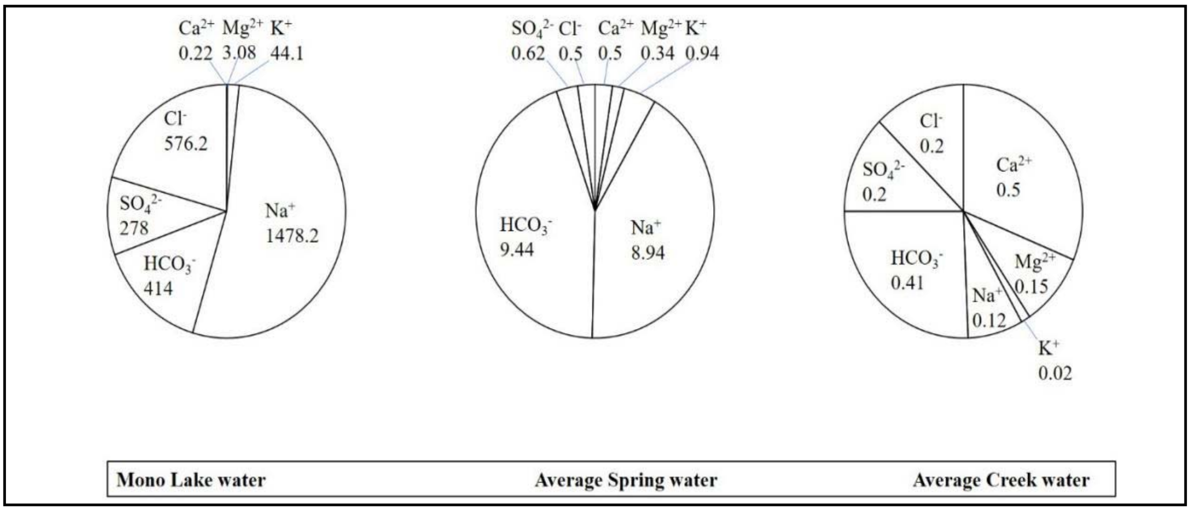

Figure 3. From Sahajpal et al., revision in progress, Pie charts showing the relative concentrations of cations and anions in miliequivalents per liter from creek and spring waters and Mono Lake water (Neumann and Dreiss 1995; Tomascak et al. 2003).

4. Concentration factor and molar concentration

To simulate the composition of Mono Lake water from evaporation of Sierran spring water Garrels and Mackenzie (1967) used the iterative thermodynamic calculation presented in Figure 4. It's just one value, but an it's a good estimate for the composition of mono lake water. Although we know that the mono lake today has a concentration factor that's greater than a thousand, probably closer to 3000.

The concentration factor is the ratio of the original value of water to the current value of water (defined as the volume of initial water/volume of water at the point, e.g., at a concentration factor of 2 half of the water has evaporated). As we can see in the diagram, sodium, potassium, sulfate, chloride, and lithium all increase by 1:1 with the concentration factor. That is to say they are conservative to at least a concentration factor of 1000.

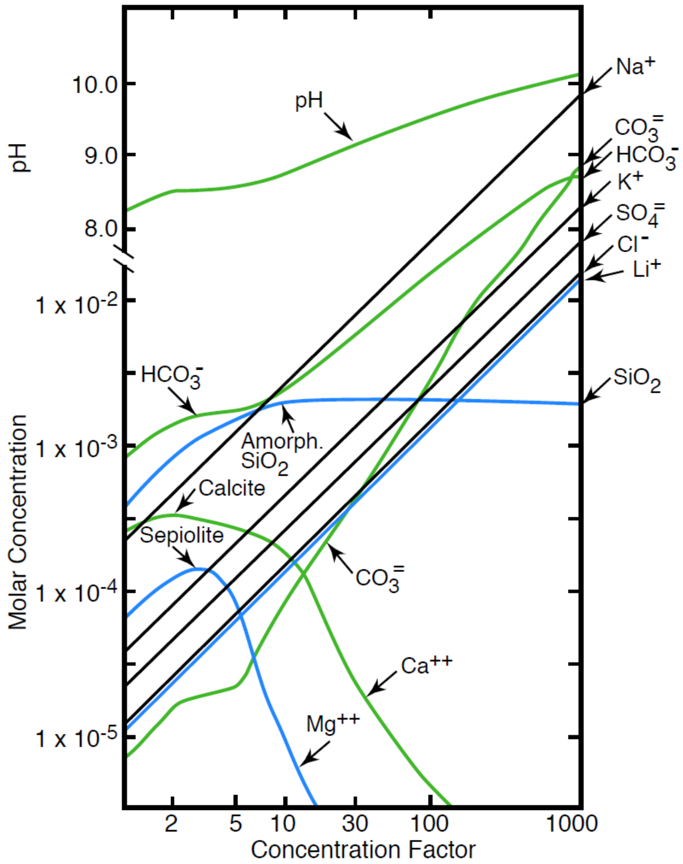

Figure 4. Garrels and Mackenzie 1967 theoretical calculation of the relationship between concentration factor and molar concentration of the original and evolved water.

As for calcium carbonate, with the increase of concentration factor, calcium carbonate soon reaches saturation and begins precipitating, so the molar concentration of calcium ion does not increase with the increase of concentration factor like the conservative ions. The molar concentration of calcium increases slightly between concentration factors of one and two. When the water concentration factor approaches 2, it is already very close to the saturation point of calcium carbonate ($CaCO_3$), so it starts to precipitate. The concentration of calcium decreases slightly between the concentration factors of about 2 and 10, and then trends to a very low values, very close to, but not zero (note the log scale of the molar concentrations). The concentration of calcium in mono lake today is about 4 parts per million by weight 40 grams per mole. As for the CO_3^{2-}, early in the evaporation process, the CO_3^{2-} minus actually goes up linearly with the concentration factor (e.g., when the concentration factor is 2, the molar concentration is about twice as high as the initial concentration). When its concentration factor is between 2 and 5, we can see that it rises slowly and is nearly in balance. But once the enrichment factor goes beyond 10, the carbonate ion has basically used up all the calcium (the other reactant in Ca^{2+} plus CO_3^{2-} goes to $CaCO_3$). After this point (known as a chemical divide), we can see that the carbonate concentration increases faster than the evaporation concentration, and that is because of the equilibrium of the carbonate system. To examine this phenomenon, note the behaviors of pH and HCO^{3-}. Note, there is a break in the y axis between 1e-2 and 8. The pH is plotted above this break pH is –log (H) so this is a separate y axis with a different scale. The pH at the initial step about 8.3, within the range of the pH of the water we drink. As the concentration factor increases, so does the pH to 8.5 or so, there is a slow incline, and then the rate increases again. And the pH of mono lake water today is 9.7. The water in Mono Lake is incredible high pH natural water, and there are some reasons for that. One of them is that the ratio of calcium to carbonate as seen in this diagram. The concentration of carbonate ion in Mono Lake is very high and the concentration of calcium ions is very low. The carbonate system has a chemical equilibrim [5].

Magnesium is also nonconservative. At the beginning the Sierran spring water has a magnesium concentration is something like eight times 10 to the minus four. The silica concentration is something like six times 10 to the minus three. So the silica to magnesium ratio is much higher than one. Initially as evaporation proceeds the magnesium ion and silica concentrations increase. When sepiolite becomes saturated and begins to precipitate the magnesium begins to decline, and like Ca eventually begins to be drawn down to very low values. This is an internal reaction:

Ca(HCO3)2==CaCO3↓+CO2↑+H2O

Mg(HCO3)2==MgCO3↓+CO2↑+H2O

MgCO3+H2O==Mg(OH)2+CO2↑

But, in contrast to the carbonate, we can see that silica does not increase rapidly but rather maintains a relatively constant composition. There are other reasons for this, such as biology- that is precipitation of SiO2 as opal.

5. Comprehensive factor analysis based on principal component analysis

In order to better characterize the changes of positive and negative ions in Mono Lake water under different concentration factors, the correlation analysis method is used for further exploration. The calculation formula of correlation analysis method is as follows:

$$\rho_{X,Y} = \frac{E(XY) - E(X)E(Y)}{\sqrt{E(X^2) - E^2(X)}\sqrt{E(Y^2) - E^2(Y)}}$$

Before the correlation analysis, we first standardized the data, because the range of pH value is obviously different from that of other ions.

Table 1. Variable distribution

	minimum value	Maximum	mean value	standard deviation
A	0.80	4.40	2.0314	1.33576
B	1.15	4.00	2.2014	.99283
C	1.16	4.10	2.1714	1.01190
D	1.30	42.00	7.8714	15.06361
E	1.60	4.50	2.6429	1.05017
F	0.00	2.05	.9529	.94863
G	2.40	5.20	3.5000	1.00333
H	0.00	2.50	1.6500	1.03360
I	2.60	3.30	3.0286	0.26904
J	2.90	4.60	3.5429	0.58269
K	8.10	9.80	8.6857	0.62029

Where A(CO_3^{2-}), B(Li^+), C(CL^-), D(SO_4^{2-}), E(K^+), F(MG^{2+}), G(Na^+), H(Ca^{2+}), I(SiO_2), J(HCO_3^-), K(PH)

Then the Pearson correlation coefficient is used to calculate the following results.

Table 2. Correlation among variables

	A	B	C	D	E	F	G	H	I	J	K
A	1.000	.928	.967	.805	.985	-.730	.936	-.914	.429	.962	.926
B	.928	1.000	.986	.824	.966	-.871	.996	-.956	.608	.983	.993
C	.967	.986	1.000	.863	.988	-.801	.980	-.931	.536	.982	.976
D	.805	.824	.863	1.000	.805	-.478	.775	-.731	.153	.825	.817
E	.985	.966	.988	.805	1.000	-.796	.971	-.930	.549	.972	.953
F	-.730	-.871	-.801	-.478	-.796	1.000	-.896	.899	-.747	-.822	-.884
G	.936	.996	.980	.775	.971	-.896	1.000	-.967	.636	.984	.991
H	-.914	-.956	-.931	-.731	-.930	.899	-.967	1.000	-.515	-.964	-.975
I	.429	.608	.536	.153	.549	-.747	.636	-.515	1.000	.522	.552
J	.962	.983	.982	.825	.972	-.822	.984	-.964	.522	1.000	.984
K	.926	.993	.976	.817	.953	-.884	.991	-.975	.552	.984	1.000

It can be seen that there are many ions in the water of Mono Lake, which show a relatively consistent change with the change of concentration factor $CO_3^{2-}$and K^+ The correlation was as high as 98.5%, Li^+ and Na^+ The high correlation between ions is mainly due to the decomposition of the original compounds into several ions dispersed in the seawater during the geological deposition

However, the high consistency between the ions indicates that there is a strong close relationship between the ions. At this time, the statistical indicators used to represent the relationship between ions are redundant. In order to better explore the real changes of ions with the concentration factor, find out the comprehensive changes that can represent the ions under different concentration factors, in this paper, principal component analysis was used to screen factors and reduce dimension

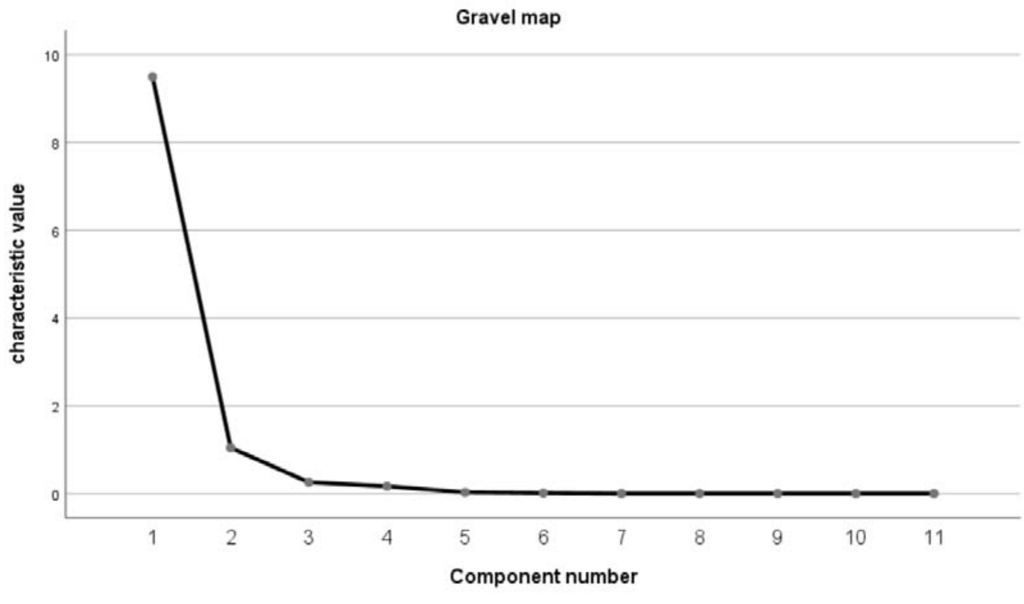

Figure 5. Graval map

It can be seen that the first two eigenvalues account for a large proportion, which means that the first and second principal components are the most important principal components. Therefore, the first two principal components are extracted to represent the comprehensive ion variables, which are used to represent the changes of ions in Mono Lake water.

Table 3. Relationship between principal component analysis and variables

V1	V2
.06	-.10
.03	.06
.05	-.03
.10	-.37
.04	.00
.04	-.37
.02	.10
-.03	-.05
-.10	.64
.04	-.02
.03	.03

It can be seen that the first principal component is mainly related to CO_3^{2-}, Li^+ and CL^-, SO_4^{2-} There was a positive correlation between et al Ca^{2+} and SiO_2 In order to simplify the study, the first principal component is used to represent the change of ions. After extracting the first principal component, the spatial interpolation method is used to obtain the following results:

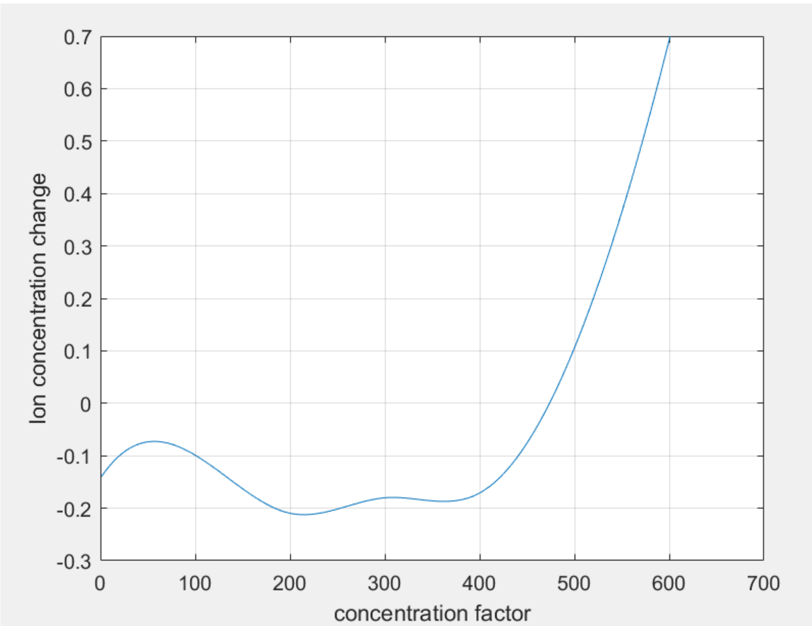

Figure 6. Variation of comprehensive variable with concentration factor

It can be seen that with the increase of concentration factor, the concentration of ions mainly shows the main characteristics of increasing and then decreasing, then stabilizing, and then continuing to increase. When the concentration factor is 0 ~ 50, it presents an upward process, and then decreases gradually from 50 ~ 100; from 100 to 400, it keeps stable, but there are also small fluctuations, and finally when it is greater than 400, it shows a rapid rising state, This comprehensive ion concentration can more intuitively and concisely show the change of ions in Mono Lake water.

6. Conclusion

On the basis of previous studies, the chemical water substances of Mono Lake are studied, through the change of geographical location and water level, the change of substance concentration and anion

IOP Conf. Series: Earth and Environmental Science **632** (2021) 022043 doi:10.1088/1755-1315/632/2/022043

content was detected. After the research, we draw two conclusions: (1) compared with carbonate, we can see that silica does not increase rapidly, but maintains a relatively constant composition. There are other reasons, such as biology, where silica precipitates into opal. (2) Based on the analysis of the relationship between the change of pH concentration factor and molar concentration in ordinary water, and inferring the reasons for the change, the change of anion and cation composition with water level was detected.

References

[1] ROBERT M. GARRELS. Origin of the Chemical Compositions of Some Springs and Lakes.
[2] Tracy L. Shirley J. Dreiss 1. Chemical evolution of shallow groundwater along the northeast shore of Mono Lake. WATER RESOURCES RESEARCH, VOL. 31, NO. 12, Pages 3171 - 3182, 1995.
[3] PAUL B. TOMASCAK, 1, 2,* N. GARY HEMMING, 2 and SIDNEY R. HEMMING2. The lithium isotopic composition of waters of the Mono Basin. Geochimica et Cosmochimica Acta, Vol. 67, No. 4, pp. 601 – 611, 2003.
[4] David B. Rogers • and Shirley J. Dreis. Saline groundwater in Mono Basin, California 2. Long-term control of lake salinity by groundwater. WATER RESOURCES RESEARCH, VOL. 31, NO. 12, pp 3151-3169, 1995.
[5] John M. Melack & Robert Jellison. Limnological conditions in Mono Lake: contrasting monomixis and meromixis in the 1990s. Hydrobiologia 384: 21 – 39, 1998.