PHYSICAL AND CHEMICAL RESEARCH OF PROCESSES OF SALT FORMATION IN THE WATER OF BALKHASH LAKE

Myrzabay Dzhetimov, Erlan Andasbayev, Ilias Esengabylov, Sayle Koyanbekova, Erkyn Tokpanov, Zhetysu State University named after I. Zhansugurov, barieva010@mail.ru

In recent years about 5.04 million tons of salts a year arrive down the River Ili to Balkhash Lake. Using water of the Ili River for filling the Kapchagaisky reservoir reduced volume of arriving water from the river to 2/3 and decreased level of the Lake. It causes mineralization, which advances forecasts. Complex research of influence of the Ili River on the current state of salt formation in Balkhash Lake is needed as well as hydrochemical research of the water area of Balkhash Lake and the Ili River. In our study the chemical analysis of the qualitative and quantitative characteristics of water with use of classical and physical and chemical methods of the analysis, such as, nuclear and absorbing, roentgen fluorescence spectrometry and crystal and optical analysis was realized. It is established that crystallization of salts begins with calcium carbonate in the form of aragonite; crystals of nesquehonite join this process, and in deposit the main carbonate of magnesium drops out. Processes of metamorfization with participation of ions of carbonate, hydro carbonate and calcium, are bringing calcite sedimentation. They occur everywhere, but processes with participation of magnesium ions are bringing magnesite or dolomite sedimentation only in extreme east stretch of the Lake. In saturated solutions of carbonates there is an increase in ions of potassium in sediment. Thus, their quantities increase a little. It is especially sharp for sulfate and sodium chloride in the direction from the west to the east. The calcium carbonate in the firm phase possesses more absorbing ability, than magnesium carbonate, and the presence of ions of potassium at sediment doesn't change structure of the last. At isothermal evaporation of mix of solutions of potassium carbonate with saturated solution of calcium carbonate, and also potassium sulfate with saturated solution of calcium sulfate and the joint sedimentation of potassium is noticed.

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Introduction

Water resources of Kazakhstan are one of the major factors stimulating the rates of its economic development. Numerous salt lakes on the territory of the republic are the source of natural salts. One of the major continental salt basins of Kazakhstan is Pribalkhashye - district of the Lake of Balkhash (Beremzhanov, 1989).

On the Ecology Chair of Zhetysu State University named after I. Zhansugurov, genesis of natural salts of Pribalkhashya was investigated and rational ways of using sulphatic lakes were proved.

In literature, there is an absence of a uniform approach to the solution of sediment formation processes in continental reservoirs. This was the reason for starting hydro chemical research on the water area of Balkhash Lake since the summer 2009. Its purpose was specification of modern salt balance of the Lake and development of forecast for prospect.

Studying of hydrochemistry of Balkhash Lake is closely connected with the problem of optimum use of water resources of its basin, including the Lake itself.

Methodology

The process of carbonates formation is observed in many modern reservoirs, but in Balkhash Lake it is the most intensive (Moon & Bekturova, 1992).

Continuous inflow of river waters which salt structure includes $\text{Ca}(\text{HCO}_3)_2$ and $\text{Mg}(\text{HCO}_3)_2$, high concentrations of salts as a result of evaporation, create conditions for displacement in the system of carbonate and calcium balance towards formation of carbonate ions according to the scheme:

The carbonate system of water of Balkhash Lake was researched repeatedly generally from the point of view of accumulating carbonate combinations in the bottom sediments of the Lake. The question of taking into account this process in salt balance of the Lake is put for the first time by M.Tarasov (Tarasov, 1961).

During the summer 2009 the detailed hydro chemical shooting of the Lake was carried out. We took 206 water samples from 116 points standing from each other at distance of 5-7 km. We took 34 water samples from the Ili River in the mouth area. General chemical water analysis and processing of the received results was realized with standard methods in hydrochemistry.

From hydro chemical point of view, Balkhash Lake is a unique reservoir; mineralization and the ratio of the main ions in Lake water naturally change its length from the west to the east. By long-term observations (1985-2009) it was established that in the southwest part of the Lake mineralization fluctuates from 0.65 to 1.42 g/l, and in the most east stretch – from 4.80 to 5.76 g/l (Snegiryova, 1970).

Comparison of some prognosis estimations with actual data shows that growth of water mineralization in recent years considerably outgoes in intensity the prognosis values (see Table 1).

Table 1: Prognosis and actual values of water mineralization of Balkhash Lake								
Year	Organization							
	KazNIGMI		ZHGU		GGI		KazGP	
	Western Balkhash	East Balkhash	Western Balkhash	East Balkhash	Western Balkhash	East Balkhash	Western Balkhash	East Balkhash
	Prognosis		actual		actual			
1985		2.53						
1989							1.97	2.63
1995	1.53	3.61					1.44	2.77
1999		3.44			1.9	4.4	1.56	
2005		3.73	1.85	4.58				

2009		4.17	2.76	6.23				
2011		5.12	3.05	6.78				
Source: Beremzhanov (1989), Dostay (2005), Andasbayev & Dzhetimov (2012)								

According to its structure water belongs to sulphatic class of sodium group with increased content of chlorides. With mineralization growth in length of the Lake the relative contents of ions of HCO_3^- , CO_3^{2-} , Ca^{2+} decreases, but the contents of ions of Cl^- , SO_4^{2-} , Mg^{2+} , Na^+ , K^+ increases (Table 2).

Table 2: Average chemical composition of water of Balkhash Lake in hydro chemical areas (summer 2009)								
Hydro-chemical area	Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	Cl ⁻	Σ Mg/l
	1/z (C) mmol/l m/l							
1	2.17 43.4	7.80 94.4	11.83 295.7	4.60 280.7	0.80 24.0	10.6 508.8	5.80 206.0	1453
2	2.05 41.1	7.15 86.9	12.60 315.0	4.30 262.4	0.80 24.0	11.5 552.7	5.20 184.2	1466
3	1.84 36.9	10.40 126.1	18.68 467.0	4.92 300.7	1.44 43.2	16.3 783.6	7.90 281.0	2038
4	1.71 34.3	11.90 145.2	24.45 611.3	5.28 322.5	1.97 59.1	18.9 905.9	11.10 393.1	2471
Western Balkhash	1.94 38.9	9.30 113.1	16.58 414.5	4.77 291.5	1.25 37.5	14.3 687.7	7.50 266.0	1849
5	1.16 23.2	17.04 207.2	36.90 922.3	7.47 456.1	1.96 59.0	25.9 124.7	19.70 700.4	3615
6	0.99 20.0	18.50 224.6	40.84 102.1	7.96 485.9	2.27 68.2	28.2 135.4	21.90 776.2	3950
7	0.99 19.8	22.80 277.2	52.40 131.0	9.55 583.3	3.44 103.2	34.80 167.3	28.40 100.9	4976
8	0.71 14.2	26.80 314.0	61.6 153.9	10.79 659	4.20 126.0	41.0 197.1	32.10 114.0	5763
East Balkhash	0.96 19.3	21.03 255.7	47.92 119.8	8.94 546	2.97 89.1	32.5 156.1	15.50 906.5	4576
Average value	1.45 29.1	15.20 184.4	32.20 806.5	6.86 418.7	2.11 63.3	23.4 1124	16.50 586.2	3212
Source: Beremzhanov (1989), Dostay (2005), Andasbayev & Dzhetimov (2012)								

Comparing values of chlorine factors of some ions (Table 3, Figure1) it is visible that in the Lake there are processes in which ions of calcium, magnesium, carbonate, hydro carbonate as well as sulfate ions take notable part. However, the processes proceeding in different places of the Lake are not of the same type. Metamorphization processes with participation of carbonate, hydro carbonate ions and calcium ions, bringing to calcite sedimentation, occur everywhere, but processes with participation of magnesium ions, bringing to sedimentation of magnesite or probably dolomite, occur only in extreme east stretch of the Lake.

Table 3: Chloric coefficients of the main ions for water of Balkhash Lake (summer 2009)

Area	C/Cl*10 ⁻²						Σ/Cl^{-1}
	Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	
1	21.0	45.8	143.5	136.2	11.6	246.9	7.05
2	22.30	47.1	171.0	142.4	13.0	300.0	7.96
3	13.10	44.8	166.1	107.0	15.3	278.8	7.25
4	8.70	36.9	155.5	82.0	15.0	230.4	6.28
5	3.30	29.5	131.7	65.1	8.4	178.0	5.16
6	2.57	28.9	131.0	62.5	8.7	174.0	5.08
7	1.96	27.4	129.7	57.7	10.2	165.7	4.92
8	1.24	27.5	135.0	57.8	11.0	172.9	5.05

Source: Beremzhanov (1989), Moon (1992), Dostay (2005), Andasbayev & Dzhetimov (2012)

Figure 1: Change of value of chloric coefficients of some ions for water of Balkhash Lake

Source: ● Beremzhanov(1989) ● Moon (1992) ● Dostay (2005)
● Andasbayev & Dzhetimov (2012)

These conclusions confirm opinion of Tarasov (1961) and others about sedimentation of carbonates from Balkhash water, but there is dissimilarity of the processes proceeding in the western and eastern parts of the Lake (Abrosov, 1983). In this connection analogy in change of concentration of the sum of hydro carbonates and carbonates on the one hand, and the sum of calcium and magnesium on another hand (Table 4, Figure 2) is very significant.

Table 4: Average ionic composition of water of Balkhash Lake in its natural state with the deduction of carbonates of calcium and magnesium (Summer 2009)

No. Area	Content of ions, 1/z (C), mmol/l								Carbonates and related Ca ⁺ and Mg ⁺		Cl ⁻
	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻	CO ₃ ²⁻	Ca ²⁺	Mg ²⁺	Na ⁺ ,K ⁺	Σ	1/ z mmol/l	% Σ	SO ₄ ²⁻
1	5.4 5.4	10.1 10.1	4.48 -	0.80 -	2.12	7.57 4.41	11.23 11.23	41.8 31.2	10.5	25.2	0.5

2	5.4 5.4	11.2 11.2	4.37 -	0.82 -	1.97	7.26 4.04	12.58 12.58	43.6 33.2	10.3	23.7	0.4
3	7.8 7.8	15.3 15.3	4.83	1.36	1.8	9.90 5.52	17.64 17.64	59.7 46.3	12.3	20.7	0.5
4	10.2 10.2	17.3 17.3	5.06 -	1.91 -	1.68	11.4 6.63	21.39 21.39	69.0 55.5	13.4	19.5	0.5
5	19.1 19.1	25.5 25.5	7.42 -	2.07 -	1.17	16.8 8.52	36.13 36.13	108.0 0 89.3	18.9	17.5	0.7
6	22.1 22.1	28.8 28.8	8.00 -	2.31 -	1.00	18.5 9.19	41.76 41.76	122.5 1 101.9 0	20.6	16.8	0.7
7	28.0 28.0	34.1 34.1	9.63 -	3.36 -	0.96	22.3 10.3	51.87 51.87	150.3 6 124.3 8	25.9	17.2	0.8
8	32.8 32.8	41.2 41.2	10.73 -	0.68 -	0.68	26.0 15.6	62.31 62.31	176.9 8 152.0 5	25.9	14.6	0.8

Source: Beremzhanov (1989), Dostay (2005), Andasbayev & Dzhetimov (2012)

Figure 2: Change of value of concentration of ionic composition of water of Balkhash Lake in its length

Source: Beremzhanov (1989), Dostay (2005), Andasbayev & Dzhetimov (2012)

If carbonates didn't participate in sedimentation process, their contents, as well as the content of chlorine ions, should increase in the 8th hydro chemical area (Burlyu-Tyubinsky stretch) approximately six times and are about 32.0 mmol/l. The observed content of carbonates in this stretch is 10.73 mmol/l, that is 21.27 mmol/l less than it would be observed in the specified case. Similar calculation for the sum of calcium and magnesium gives 31.46 mmol/l, that is close figure.

If we compare ionic composition of the Lake water with the same structure, but minus calcium and magnesium containing in it, (Table 4), it is possible to see that the absolute total quantity of carbonates

of calcium and magnesium grows from 10.56 in the west to 25.93 mmol/l in the east (increase by 2.5 times). However their relative contents in general concentration of salts in the same direction fall almost in two times. In another words in the direction from the west to the east Balkhash water unites according to the content of carbonate combinations and first of all calcium as a result of sedimentation that is convincingly confirmed by the data of Table 4. If carbonic calcium is present at all areas of the Lake, carbonic magnesium is absolutely absent in the water of the western stretch, appearing only in the eastern half of the reservoir. Here as approaching the eastern part of the Lake, the tendency to increase in the content of this salt is clearly visible. All other salts ($\text{Mg}(\text{HCO}_3)_2$, MgSO_4 , Na_2SO_4 , NaCl , KCl) are present in the Lake water everywhere (Table 5). Thus their quantity increases a little, especially sharp for sulfate and sodium chloride in the direction from the west to the east.

Table 5: Average salt composition of water of Balkhash Lake in hydro chemical areas (mmol/l, % from the sum of salts)							
Hydro-chemical areas	CaCO_3	$\text{Ca}(\text{HCO}_3)_2$	MgCO_3	$\text{Mg}(\text{HCO}_3)_2$	MgSO_4	Na_2SO_4	$\text{NaCl} + \text{KCl}$
1	0.80/3.6	1.37/6.3	-	3.23/14.8	4.57/20.9	6.03/27.6	5.80/26.6
2	0.80/3.6	1.25/5.7	-	3.05/13.9	4.10/18.8	7.35/33.7	5.25/24.1
3	1.44/4.6	0.40/1.3	-	4.52/14.6	5.88/19.0	10.42/33.7	8.26/26.71
4	1.71/4.5	-	0.26/0.68	5.28/13.9	6.36/16.7	12.54/32.9	1.91/31.3
Comparison Western Balkhash	1.25/4.5	0.69/2.5	-	4.08/14.6	5.22/18.7	9.08/32.63	7.50/26.9
5	1.16/2.1	-	0.80/1.4	7.47/13.55	8.77/15.9	17.19/31.2	19.71/35.8
6	0.99/1.6	-	1.28/2.1	7.96/13.2	9.26/15.3	18.94/31.2	21.90/36.3
7	0.99/1.3	-	2.45/3.2	9.55/12.5	10.80/14.2	24.00/31.5	28.40/37.3
8	0.71/0.8	-	3.49/3.9	10.79/12.2	11.52/13.1	29.48/33.4	32.12/36.4
Comparison East Balkhash	0.96/1.37	-	2.01/2.87	8.94/12.8	10.08/14.4	22.42/32.1	25.50/36.5
			0.66/1.3	6.86/14.1	7.68/15.7	15.72/32.1	26.50/33.8
Source: Andasbayev & Dzhetimov (2012)							

Practical part

Process of sedimentation of calcium carbonates and magnesium of the water of Balkhash Lake is one of the factors which are constantly reducing the salt stock of the Lake, its mineralization and so is included in the used part of its salt balance.

In this connection research of the condition of carbonate and calcium balance in Balkhash Lake water in modern and long-term periods is of interest. The results of the calculation done by us for each hydrochemical area of the Lake (206 samples) during the summer period since 2009 are averaged and given in Table 6 and presented graphically on Figure 3 and 4.

Table 6: Characteristic of the condition of carbonate and calcium balance of the water of Balkhash Lake and the Ili River (August, 2009)									
No. Area	t°, C	pH	Ca^{2+} Mg/l	HCO_3^- Mg/l	CO_2		$\text{CO}_3^{2-} \cdot 10^{-6}$	$\text{Ca}^{2+} \cdot \text{CO}_3^{2-} \cdot 10^{-9}$	S/ SO_4
					Free	linked			
1	23.0	8.38	42.5	273.4	1.28	7.38	134.48	16.5	4.9
2	23.0	8.47	39.5	266.7	1.12	6.12	171.17	20.0	6.0

3	23.6	8.48	36.2	294.7	1.03	7.18	213.51	19.4	5.8
4	23.6	8.65	33.7	308.8	0.77	6.63	330.57	25.5	7.7
5	24.1	8.80	23.4	452.5	0.69	7.83	742.50	3.2	9.1
6	24.3	8.91	12.2	488.2	0.57	7.48	982.18	31.7	9.7
7	24.2	9.00	19.2	587.6	0.58	9.30	1512.40	37.2	11.5
8	24.8	9.05	13.6	654.7	0.56	8.34	2071.03	31.2	9.6
Channel River Ili	25.0	8.44	64.1	170.8	0.68	4.88	81.60	17.6	5.5
Source: Andasbayev & Dzhetimov (2012)									

Figure 3: Change of value of mineralization of Balkhash Lake in its length

Source: Andasbayev & Dzhetimov (2012)

Figure 4: Dependence of the content of carbonates and hydrocarbonates of calcium and magnesium on the value of mineralization of the water of Balkhash Lake (summer 2009)

Source: Andasbayev & Dzhetimov (2012)

Apparently, the water of Balkhash Lake in its water area is oversaturated with carbonate of calcium, supersaturation is unequal and grows in the east direction from 3.6 to 15.2. Comparing average values of product of activity of Ca^{2+} and CO_3^{2-} in the 1st and the 8th hydro chemical areas it is visible that they

practically don't change: there is some increase of value $\text{Ca}^{2+} + \text{CO}_3^{2-}$ from the 2nd to the 6th areas, then its decrease upon transition to the 7th and the 8th areas.

On Figure 1 and 2 there are also curves of changing of product of activities of ions of calcium and carbonate ions, the values of supersaturation in the water of Balkhash Lake received by different authors during 1985-2009.

Significant supersaturation of natural waters with carbonate of calcium is not infrequent phenomenon. So for example, in summer saturation of water with calcium carbonate exceeded the norm in the Kapchagaysky reservoir in 58 times, in some ponds of droughty zone - in 19 times, in lakes of the Balkhash-Alakol basin - in 3-9 times, in Issyk Lake - in 3-5 times, etc.

O.Alekin and N.Moricheva showed that the organic substance makes stabilizing impact on solutions oversaturated in relation to calcium carbonate (Alekin & Morichev, 1961)

According to our research the permanganate oxidability of the water of Balkhash Lake increases from 7.89 in the western part to 10.0 mg O/l in the eastern part.

The authors of this work did calculations of the quantity of carbonates fallen in the Lake for the period of 2009-2012. The results on ionic structure of the Ili River feeding Balkhash Lake are used for this purpose.

It appeared that the volume of carbonates from flow of salts during this period was 56 % in average (Table 7).

Table 7: Average annual chemical composition of water of the Ili River										
River	Years	Ionic structure, mg/l						Sum of ions of mg/l	Carbonates and hydro carbonates of Ca and Mg	
		Ca ²⁺	Mg ²⁺	Na ⁺ +K ⁺	HCO ₃ ⁻	SO ₄ ²⁻	Cl ⁻		mg/l	%
Ili	1985-86	41.0	10.5	8.5	144.0	30.4	9.2	244	188	77
	2005-07	42.0	23.0	50.0	198.0	91.0	24.0	428	255	59
	2008-09	53.2	15.5	69.4	202.3	115.9	39.7	496	264	53
Source: Andasbayev & Dzhetimov (2012)										

For clarification of regularities of continental salt formation isothermal evaporation in the laboratory environment of the water of Balkhash Lake was realized. It was established that the way of crystallization of salts at gradual concentrating of water differs from the order of salt extraction from waters of sea type. It is defined as it was specified above, by originality in the salts ratio: small content of sodium chloride (twice less than in sea water); high content of sodium sulfate; Balkhash water is rich in carbonate ions and magnesium ions. In this work the data on measuring ionic structure (the main salts) and some microelements of Balkhash water at isothermal evaporation at the stage of carbonates crystallization are provided (Table 8). Salt crystallization begins with calcium carbonate in

the form of aragonite at total amount of salts of 16.6 g/l; the content of CaCO_3 reaches 110 mg/l, in comparison with the initial one - 40 mg/l. In process of aragonite fall, concentration of CaCO_3 in the solution decreases at first, and then increases again.

Table 8: Results of the analysis of the samples selected in the course of isothermal (25°C) evaporations of Balkhash water									
Density g/cm^3	pH	CaCO_3	MgCO_3	$\text{Mg}(\text{HCO}_3)_2$	MgSO_4	Na_2SO_4	NaCl	Sum of salts	Firm phase
		mg/l			g/l				
1.003	8.8	40.0	75.9	680.4	0.5	1.4	1.4	4.1	-
1.014	9.2	70.0	375.5	651.4	1.4	2.2	2.9	7.7	-
1.015	9.2	85.0	750.9	834.0	2.1	4.2	4.8	12.9	-
1.013	9.2	110.1	1426.0	702.3	1.9	6.5	5.8	16.6	
1.024	9.4	105.1	2236.0	1053.5	3.5	10.4	9.9	27.2	Nesquehonite
1.021	9.4	50.0	1134.0	1675.3	4.7	11.5	9.1	28.2	
1.032	9.4	115.1	2636.8	556.0	4.8	9.1	12.2	29.2	aragonite
1.097	9.4	185.1	1531.5	1960.7	18.6	12.1	36.7	71.1	Nesquehonite
1.095	9.0	155.1	3143.1	2136.3	16.1	46.6	45.9	114.0	Main magnesium carbonate
1.127	8.6	305.0	2897.3	2077.7	39.3	53.7	70.4	168.8	
Source: Andasbayev & Dzhetimov (2012)									

When general mineralization reaches 27.2 g/l aragonite (CaCO_3) is joined by nesquehonite ($\text{MgCO}_3 \cdot 3\text{H}_2\text{O}$). The content of MgCO_3 in the solution, increased to 2.2 g/l, decreases in 2 times (from 2.2 to 1.1 g/l). At general stock of carbonates about 5.4 g/l instead of good crystals of nesquehonite the main magnesium carbonate ($3\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$) settles down in the form of microcrystalline almost amorphous mass. After that the growth rate of concentration of carbonates decreases. Sparingly soluble salts are replaced by well soluble sulfates and chlorides of sodium and magnesium. The behavior of potassium in the course of isothermal evaporation of Balkhash water was studied. Data available in literature concern generally potassium distribution at concentrating of sea type waters or analysis of data in content of potassium in waters with different mineralization.

Earlier we ascertained that the content of potassium in solution increases with growth of general mineralization, excluding the stage of carbonates sedimentation. At the beginning of evaporation (Table 9) concentration of potassium increases in the liquid phase in 61 times (from 3 to 185 mg/l).

Table 9: Change of the content of potassium in the course of isothermal evaporation of the water of Balkhash Lake			
Content of potassium, mg/l	Content of chlorine, mg/l	Sum of salts %	$\text{K} \cdot 10^3 / \text{Cl}^-$
3	0.9	0.4	3.5
135	1.0	0.4	123.2
150	1.3	0.5	105.8
185	1.8	0.7	93.6
147	1.5	0.7	88.7
202	1.9	0.9	89.8
400	4.3	1.9	82.1
525	5.4	2.7	85.4

837	8.5	3.6	85.7
1437	13.7	5.3	85.6
2632	25.4	10.4	86.1
4125	37.9	14.9	87.5
Source: Andasbayev & Dzhetimov (2012)			

Analysis and discussion

The results of the experiments (Table 10) showed that in saturated carbonates solutions there is an increase of potassium ions to sediment, and in the increased concentration areas absorption decreases from 200-400 mg/l. In very diluted solutions absorption of potassium ions is observed. It is necessary to note that CaCO_3 in the firm phase has more absorbing ability than MgCO_3 , and according to the crystal and optical analysis the presence of potassium ions in the sediment does not change the structure of the latter. Joint sedimentation of potassium is observed also at isothermal evaporation (25°C) of the mixture of potassium carbonate solutions with saturated solution of calcium carbonate, and also potassium sulfate with saturated solution of calcium sulfate (Andasbayev & Dzhetimov, 2012) (Table 11).

Table 10: Absorption of potassium ions by calcium and magnesium carbonates, experiments results							
Sample	Content in solution, mg/l		The absorbed potassium, %	Sample	Content in solution, mg/l		Absorbed potassium [%]
	K^+	Ca^+			K^+	Ca^+	
1	2	3	4	5	6	7	8
Solution K_2CO_3 + sediment CaCO_3				Solution K_2CO_3 + sediment MgCO_3			
Starting	4.0	-	-	starting	7.2	-	-
Contact	4.3	10.4	-	contact	7.4	40.1	-
Starting	15.0	-	-	starting	18.0	-	-
Contact	15.5	11.5	-	contact	18.0	42.5	-
Starting	61.0	-	-	starting	56.0	-	-
Contact	53.0	5.4	13.1	contact	58.0	36.5	-
1	2	3	4	5	6	7	8
Starting	70.0	-	-	starting	185.0	-	-
Contact	47.0	8.5	32.8	contact	185.0	27.9	-
Starting	200.0	-	-	starting	360.0	-	-
Contact	183.0	0.6	8.5	contact	360.0	25.5	-
Starting	450.0	-	-	starting	635.0	-	-
Contact	425.0	0.6	5.5	contact	635.0	20.6	-
Starting	690.0	-	-	starting	750.0	-	-
Contact	660.0	0.6	4.3	contact	720.0	3.3	-
starting	860.0	-	-	starting	825.0	23.1	3.0
Contact	840.0	0.6	2.3	contact	800.0	23.1	3.0
Solution KCl + sediment CaCO_3				Solution KCl + sediment MgCO_3			
starting	4.3	-	-	starting	9.0	-	-
Contact	4.3	10.2	-	contact	9.0	37.7	-
starting	19.0	-	-	starting	12.0	-	-
Contact	18.5	6.1	2.6	contact	12.0	37.7	-
starting	67.0	-	-	starting	62.0	-	-
Contact	58.0	7.0	13.4	contact	62.0	36.4	-
starting	166.0	-	-	starting	240.0	-	-

Contact	140.0	8.7	15.6	contact	240.0	36.4	-
starting	400.0	-	-	starting	320.0	-	-
Contact	380.0	11.5	5.0	contact	320.0	38.9	-
starting	690.0	-	-	starting	660.0	-	-
Contact	670.0	11.5	2.8	contact	630.0	42.5	4.5

Source: Andasbayev & Dzhetimov (2012)

Table 11: The results of experiments on isothermal evaporation of solutions of potassium and calcium salts

Content of K in solution mg/l	Content of Ca in solution mg/l	Absorbed potassium, %	Firm phase
solution $K_2CO_3 + CaCO_3$			
700.0	8.0	-	Aragonite
600.0	6.6	14.0	-
Solution $K_2SO_4 + CaSO_4$			
537.0	521.0	-	-
760.0	751.5	-	- gypsum
600.0	666.3	21.0	

Source: Andasbayev & Dzhetimov (2012)

Conclusion

On the basis of the made experiments it is possible to make a conclusion that one of the main responsible things in joint potassium sedimentation are carbonate and calcium sulfate and in less measure magnesium and calcium carbonates.

The great value for diagnostics of deposit represents distribution of microelements in natural waters among which the special place is taken by boron. The behavior of boron in the course of evaporation of sea water and the solutions imitating sea water is studied rather well, but there are no data in this relation for waters of continental origin (Beremzhanov & Bolibok, 1986).

Evaporating Balkhash water it was interesting to observe boron distribution between the firm and liquid phases. Proceeding from the received data presented in Table 12, you can see that boron behaves at evaporation of Balkhash water similar to change of potassium concentration. Its content in the liquid phase increases in the beginning from 1.8 to 5.6 mg/l, and then a half of the boron content falls out together with carbonates. The values of boron-chloric coefficients decrease up to 3.0.

Table 12: Change of the boron content in the course of isothermal evaporation of the water of Balkhash Lake

Content of boron, mg/l	Content of chlorine, mg/l	$B \cdot 10 / Cl^-$	Sum of salts, %
1.8	0.8	2.9	0.3
5.6	1.2	14.9	0.5
2.3	1.3	5.8	0.5
2.9	1.8	10.2	0.7

2.7	2.9	3.0	1.3
8.0	5.9	4.3	2.6
10.4	6.5	5.1	2.9
19.5	11.6	5.3	3.9
27.0	13.7	5.8	5.3
43.0	25.4	5.1	10.4
67.5	37.9	5.2	14.9
Source: Andasbayev & Dzhetimov (2012)			

In the solutions of boric acid being in contact with the firm phase in the form of aragonite and the main magnesium carbonate (Table 12) decrease in boron concentration is observed. All this says that boron as isomorphic impurity is entrained to the sediment with calcium and magnesium carbonates. It is favoured by the fact that the ionic radius of complex ion BO_3^{3-} in which form boron the most often appears in natural waters equals to 0.136, and at CO_3^{2-} it equals to 0.129 that is 4 % higher, but as borate ion has a bigger charge, this discrepancy is compensated.

References

- Abroso, V. N. (1983). Ozero Balhash [*Balkhash Lake*]. Leningrad, Russia, Nauka.
- Alekin, O. A. & Morichev, N. P. (1961). Izmenenie nassyshhennosti karbonatom kalcia rechnoi vody pri smeshenii eio s morskoi vodoi [Change of saturation with calcium carbonate of river water at its mixture with sea water]. *Gidrohimiicheskie materialy* [*Hydrochemical materials*], 31, pp. 95-107. Novosibirsk, Russia: Kniga.
- Andasbayev, E. & Dzhetimov, M. (2012). Fizicheskoe i himicheskoe issledovanie processov soleobrazovaniya v vode ozera Balhash [Physical and chemical research of processes of salt formation in the water of Balkhash Lake]. Taldykorgan, Kazakhstan: Lazer. ISBN 9864-2.
- Beremzhanov, B. A. & Bolibok, S. S. (1986). Povedenie broma, ioda i bora v processe isotermicheskogo isparenija kontinentalnyh vod [Behavior of bromine, iodine and boron in the course of isothermal evaporation of continental waters]. *Journal Himija i himicheskaja tehnologija* [*Chemistry and chemical technology*], 16, pp. 5-10. Almaty, Kazakhstan, Jestestvoznanie.
- Beremzhanov, B. A. (1989). Soleobrazovanie v nekotoryh kontinentalnyh basseinaх Kazahstana. [*Formation of salts in some continental basins of Kazakhstan*]. Almaty, Kazakhstan: Kniga.
- Dostay, Z. (2005). Nauchnaja osnova upravlenija gidro-ekologicheskim sostojaniem drenaznyh basseinov v Centralnoi Azii [*Scientific basis for management of hydro-ecological condition of drainage basins in Central Asia*]. Almaty, Kazakhstan: Isskustvo.
- Moon, A. I. & Bekturova, A. B. (1992). Raspredelenie mikroelementov v vodoiomah Kazahstana. [*Distribution of microelements in reservoirs of Kazakhstan*]. Almaty, Kazakhstan: Nauka.
- Moore, J. & Ramamurti, S. (2010). Tjazholye metally v prirodnyh vodah [*Heavy metals in natural waters*]. Moscow, Russia: Mir.
- Tarasov, M. N. (1961). Gidrohimiya ozera Balhash [*Hydrochemistry of Balkhash Lake*]. Moscow, Russia: Academy of Sciences of the USSR.