

FORMATION PECULIARITIES OF PHYSICAL AND CHEMICAL COMPOSITION OF HIGHLY MINERALIZED EDGE WATER

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ВИВЧЕННЯ ОСОБЛИВОСТЕЙ ФОРМУВАННЯ ФІЗИКО-ХІМІЧНОГО СКЛАДУ ВИСОКОМІНЕРАЛІЗОВАНИХ ПЛАСТОВИХ ВОД

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ABSTRACT

Purpose. To study the formation peculiarities of the physical and chemical composition of highly mineralized edge waters in oil and gas fields.

Methods. The correlation relationships between the macroions of the edge water were established by calculation of the Pearson correlation coefficient. In order to determine the complex influence of the concentrations of several ions on the individual ion concentration, the methodology of multiple correlation-regression analysis was used.

Findings. The empirical dependences between concentrations of individual ions in highly mineralized edge waters were obtained as a result of the study.

Originality. The dependences between the general water mineralization and content of macroions, as well as the complex influence of several ions on the individual ion concentration, were determined.

Practical implications. The established dependences can be used for carrying out laboratory analyses of edge water.

Keywords: edge water, mineralization, Pearson criterion, anion, cation, correlation-regression dependence

1. INTRODUCTION

Natural resources of oil and gas are usually accompanied by the presence of edge water. During their long-term operation, oil and gas fields "age". When oil deposits become depleted, the production stream is water-cut and greater volumes of edge water are ejected onto the surface. At the same time, edge waters are a byproduct, whose usage in national economy and industry is significantly limited. In fact, edge water is considered to be environmentally hazardous waste of oil industry and the only real way for its reclamation is its usage in the formation pressure maintenance systems (FPMS). If there is no FPMS in the field, edge waters are buried or returned into underground horizons (Mandryk, Pukish, & Mihajlúk, 2015).

Edge waters are considered environmentally hazardous because they comprise high concentrations of diluted salts which act as contaminating substances onto the environment components in such conditions. Storage, trans-

portation and reclamation (burial) of edge waters is a complex process from the technological point of view, since FPMS use high pressures; moreover, edge water is an aggressive medium. Thus, the possibility of the pipeline rupture, destruction of casing string walls and other production equipment caused by edge waters is very high.

Therefore, studying physical and chemical properties of edge waters and regularities of their formation is an urgent task.

It is known that the main components of diluted salts in edge waters are chloride ion, sulphate ion, hydrocarbonate ion, sodium ion, potassium ion, calcium ion, and magnesium ion. Salts, diluted in water, interact in accordance with the mechanism provided below.

Sodium ion is the most migratable among all cations, and it is practically an ideal migrant that does not form insoluble salts and can precipitate only as a result of supersaturation of the solution with salts. There are hardly any chemical barriers for the sodium cation, therefore it is the main cation of edge waters.

Calcium ion is also a good migrant but its concentration can decrease due to formation of the insoluble or slightly soluble salts, i.e. calcium sulphate and carbonate. Calcium hydrogen carbonate is a soluble salt but it oxidizes to the insoluble calcium carbonate and precipitates in the process of water transportation.

Calcium chloride is a very soluble salt and the presence of calcium in the solution provides for the presence of calcium cation in edge water. It should be noted that solubility and precipitation of calcium cation are reverse processes in natural environment therefore saturation of water with calcium ion and reduction of its concentration in water can take place depending on the conditions.

Chemical properties of magnesium cation are similar to those of calcium cation. However, magnesium sulphate is a very soluble salt which, together with good solubility of magnesium chloride, provides for its good migration properties. According to the data (Perfilova & Makhlaev, 2009), magnesium is the second most spread element after calcium in rivers and soils.

Calcium cation prevails in edge water which is connected with processes of dolomitisation (Li, 2013): $2CaCO_3 + Mg^{2+} \rightarrow CaMg(CO_3)_2 + Ca^{2+}$.

Migration capability of chloride ion is much different from that of other anions. Chloride ion forms very soluble salts with all main cations and it can be hardly sorbed by rocks, which ensures its transportation by water.

Hydrocarbonate ion prevails in fresh water. Its content in highly mineralized waters is limited due to the presence of calcium and magnesium ions that form unstable water-soluble salts with hydrocarbonates which subsequently precipitate as insoluble carbonates.

Sulphate ion holds the second place after the carbonates in fresh water. At the same time, the content of sulphate ion is very low in highly mineralized water. It is caused by the presence of surplus content of calcium and magnesium ions that are in fact a chemical barrier for sulphate ion.

General mineralization of edge water can vary within a wide range and reach 400 g/l (Kalacheva, Fedorova, & Portnyagin, 2016).

2. MATERIALS AND METHODS

We have studied physical and chemical composition of edge water in order to determine regularities of its formation. Edge water of Okhtyrskye oil field region was taken for the analysis. The analytical studies were conducted in accordance with the certified methodology. To investigate regularities, the obtained data were statistically processed.

In 2013 – 2016, we studied 45 results of edge water analysis.

The Pearson criterion was calculated in pairs for each cation and ion in edge water. The values of the diluted salts concentration were calculated in mol/dm³. General mineralization of the water was calculated in mol/dm³ as a sum of concentrations of all the studied macroions.

3. DISCUSSION

We adopted the following general classification of correlational relationships to evaluate their strength:

- strong or tight at the correlation coefficient $r > 0.70$;
- medium at $0.50 < r \leq 0.70$;
- moderate at $0.30 < r \leq 0.50$;
- weak at $0.20 < r \leq 0.30$;
- very weak at $r \leq 0.20$.

Calculated Pearson's correlation coefficients in detail are presented in Table 1.

Table 1. Calculated Pearson's correlation coefficients among the components of diluted salts in edge water

	Cl	SO ₄	HCO ₃	Ca	Mg	K+Na	mineralization
Cl	1.00						
SO ₄	-0.55	1.00					
HCO ₃	-0.15	-0.26	1.00				
Ca	0.84	-0.63	-0.09	1.00			
Mg	0.22	-0.18	0.11	0.17	1.00		
K+Na	0.96	-0.44	-0.18	0.67	0.11	1.00	
mineralization	0.99	-0.53	-0.15	0.82	0.20	0.97	1.00

As can be seen from the results of the calculations, there is a direct tight correlational relationship between the general water mineralization and concentration of sodium and calcium cations (the correlation coefficients are 0.97 and 0.82 respectively), as well as of chloride anion (the correlation coefficient is 0.99).

Correspondingly, there is also a tight relationship between chloride anion and calcium anion (the correlation coefficient is 0.84), as well as between chloride anion and sodium cation (the correlation coefficient is 0.96).

Calcium and sodium cations have a direct medium relationship between themselves (the correlation coefficient is 0.67) which is close to the value of the tight relationship (0.70). The reverse medium relationship can also be observed between calcium cation and sulphate anion (-0.63). The strength of the correlational relationship in this case also approaches the value of the strong relationship.

Besides, the reverse medium correlational relationship was also established between sulphate anion and chloride anion, as well as between the general water mineralization and sulphate cation. However, the value of the correlation coefficient both in the first (-0.55) and the second (-0.53) cases is close to the moderate relationship (0.49).

The value of the relationship was weak or very weak between other pairs of macrocomponents of salts in edge water.

It should also be noted that, notwithstanding the absolute value of the correlation coefficient (i.e. the strength of the relationship), the concentration of sulphates in edge water is inversely related to the concentrations of any macroion in it, including general mineralization.

Based on the relationships established above, we developed dependences between the concentration values of salts components in edge water, for which tight and medium correlation relationships were established (Figures 1 – 4).

Figure 1 shows the dependence between the concentration of chlorides and general mineralization of edge water.

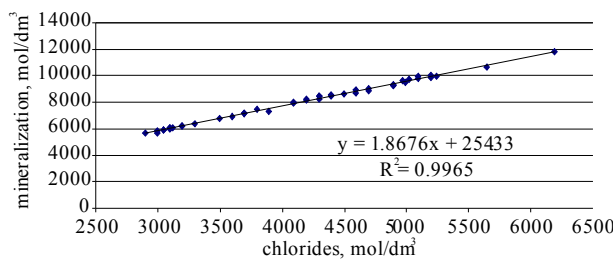


Figure 1. Dependence of chloride ion concentration on the general water mineralization in edge water

As can be seen from the dependence shown in Figure 1 and according to the results of the calculations, we found that the relationship between the general water mineralization and content of chloride ion can be determined using the linear dependence:

$$C(\text{min}) = 1.8676 C(\text{Cl}) + 254.33. \quad (1)$$

Furthermore, the determination coefficient is $R^2 = 0.99$, i.e. the dependence is correct for 99% of cases.

Figure 2 shows the dependence of sodium ion content on the general water mineralization.

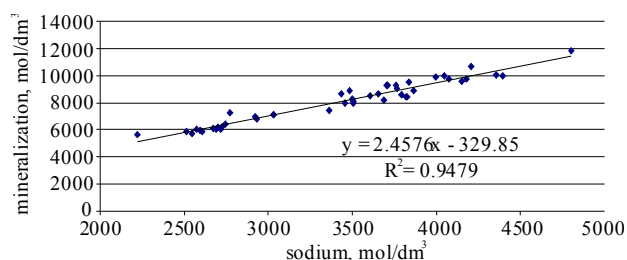


Figure 2. Dependence of sodium ion concentration on the general water mineralization in edge water

As can be seen from the dependence shown in Figure 2 and according to the results of the calculations, we found that the relationship between the general water mineralization and content of sodium ion can be determined using the linear dependence:

$$C(\text{min}) = 2.4576 C(\text{Na}^+) - 339.85. \quad (2)$$

Furthermore, the determination coefficient is $R^2 = 0.95$, i.e. the dependence is correct for 95% of cases.

Figure 3 shows the dependence of calcium ion content on the general water mineralization.

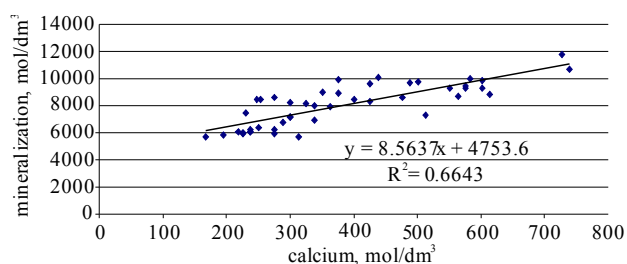


Figure 3. Dependence of calcium ion concentration on the general water mineralization in edge water

As can be seen from the dependence shown in Figure 3 and according to the results of the calculations, we

found that the relationship between the general water mineralization and calcium ion content can be determined using the linear dependence:

$$C(\text{min}) = 8.5637 C(\text{Ca}^{2+}) + 4753.6. \quad (3)$$

Furthermore, the determination coefficient is $R^2 = 0.66$, i.e. the dependence is correct for 66% of cases.

Figure 4 shows the dependence of sulphate ion content on the general water mineralization.

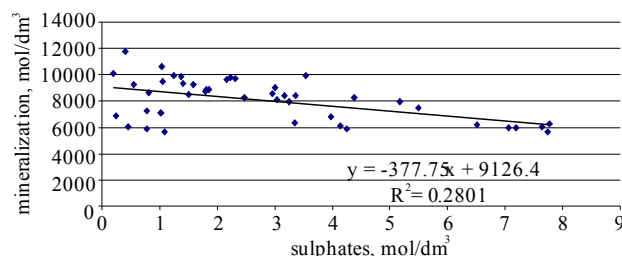


Figure 4. Dependence of sulphate ion concentration on the general water mineralization in edge water

As can be seen from the dependence shown in Figure 4 and according to the results of the calculations, we found that the relationship between the general water mineralization and content of sulphate ion can be determined using the linear dependence:

$$C(\text{min}) = -377.75 C(\text{SO}_4^{2-}) + 9126.4. \quad (4)$$

However, the determination coefficient is $R^2 = 0.28$, i.e. the dependence is correct only for 28% of cases.

We developed similar dependences for such pairs as chlorides-sodium, calcium-sodium, calcium-chlorides, sulphates-chlorides, sulphates-calcium.

The dependence has the following form for the pair chlorides-sodium:

$$C(\text{Na}^+) = 0.7102 C(\text{Cl}^-) + 445.13. \quad (5)$$

The determination coefficient is 0.92.

The relationship in the pair calcium-sodium is determined with the help of the dependence:

$$C(\text{Ca}^{2+}) = 0.1607 C(\text{Na}^+) - 163.08. \quad (6)$$

The determination coefficient is 0.45.

The relationship in the pair calcium-chlorides is determined with the help of the dependence:

$$C(\text{Ca}^{2+}) = 0.15 C(\text{Cl}^-) - 244.31. \quad (7)$$

The determination coefficient is 0.72.

The dependence has the following form for the pair chlorides-sulphates:

$$C(\text{SO}_4^{2-}) = -0.0014 C(\text{Cl}^-) + 8.872. \quad (8)$$

The determination coefficient is 0.30.

The relationship in the pair sulphates-calcium is determined with the help of the dependence:

$$C(\text{SO}_4^{2-}) = -0.0092 C(\text{Ca}^{2+}) + 6.3995. \quad (9)$$

The determination coefficient is 0.3929.

We calculated the ratio between ions concentrations and the general water mineralization.

Table 2 shows the results of the calculations.

Table 2. Ratio between ions concentrations and the general water mineralization

Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻	Ca ²⁺	Mg ²⁺	K + Na
0.525566	0.000139	0.000182	0.060849	0.008974	0.404290
0.527136	0.000171	0.000215	0.062069	0.010917	0.399492
0.528698	0.000207	9.21E-05	0.064871	0.010934	0.395198
0.529444	0.000204	6.77E-05	0.069232	0.007859	0.393193
0.525158	0.000124	0.000220	0.05834	0.010785	0.405372
0.525666	0.000110	0.000211	0.060658	0.009335	0.404020
0.519293	3.55E-05	0.000347	0.048850	0.009149	0.422326
0.515520	0.000209	0.000000	0.042170	0.008529	0.433572
0.515975	0.000524	0.000282	0.039222	0.013883	0.430114
0.514552	0.000651	0.000201	0.045649	0.004776	0.434171
0.514552	0.000651	0.000201	0.045649	0.004776	0.434171
0.527264	6.01E-05	0.000280	0.064783	0.008190	0.399423
0.529142	0.000191	0.000530	0.055307	0.022373	0.392457
0.533142	0.000106	0.001095	0.070299	0.015606	0.379752
0.524867	3.41E-05	0.000119	0.061585	0.006443	0.406953
0.518103	0.000142	0.000449	0.042152	0.014210	0.424945
0.517098	0.000132	0.001019	0.046783	0.008602	0.426366
0.510372	7.43E-05	0.000462	0.039235	0.002088	0.447769
0.508527	0.000736	0.000375	0.030884	0.008827	0.450650
0.512746	0.001211	0.000135	0.037955	0.010662	0.437291
0.510417	0.001261	0.000231	0.036139	0.008354	0.443598
0.510837	0.000724	0.000171	0.033318	0.010368	0.444583
0.508753	0.001358	0.000351	0.029485	0.012462	0.447590
0.513948	0.001048	0.000193	0.044318	0.006112	0.434382
0.513133	0.000407	0.000251	0.042384	0.004763	0.439062
0.509758	0.000531	0.000267	0.036536	0.004619	0.448289
0.521160	0.000228	0.000102	0.051269	0.010370	0.416871
0.515779	0.001177	0.000167	0.037563	0.016884	0.428430
0.515355	0.000587	0.000177	0.042477	0.009339	0.432065
0.512486	0.001246	0.000192	0.038166	0.010157	0.437752
0.525863	0.000151	0.000000	0.059227	0.010890	0.403869
0.516587	0.000237	0.000124	0.050288	0.002608	0.430157
0.516098	0.000224	0.000166	0.044239	0.007895	0.431377
0.518436	0.000177	7.08E-05	0.047291	0.008967	0.425057
0.519435	9.42E-05	0.000162	0.055016	0.002928	0.422365
0.515947	0.000373	0.000246	0.040061	0.012466	0.430907
0.512221	0.000355	0.000302	0.037792	0.007644	0.441687
0.518941	0.000298	0.000121	0.051466	0.006123	0.423050
0.520649	0.000333	0.000177	0.038904	0.022482	0.417453
0.508466	0.000375	0.000426	0.029959	0.008700	0.452074
0.512106	0.000344	0.000350	0.032116	0.013287	0.441798
0.508189	0.000399	0.000497	0.029350	0.008995	0.452571
0.529045	9.65E-05	0.000281	0.069293	0.007126	0.394158
0.515851	1.87E-05	0.000179	0.043549	0.00755	0.432852
0.512681	0.000680	0.000394	0.039097	0.008324	0.438824

As can be seen from the results of the calculations, the concentration of chlorides in edge water in relation to the mineralization varies in the range from 0.5082 to 0.53331 and the average value is 0.5179.

The concentration of sodium in edge water in relation to the mineralization runs from 0.3798 to 0.4483 and the average value is 0.4252.

The concentration of calcium in edge water in relation to the mineralization varies in the range from 0.0295 to 0.0703 and the average value is 0.047.

The concentration of sulphates in edge water in relation to the mineralization varies in the range from 0.00003 to 0.00068 and the average value is 0.000404.

These dependences testify to the existence of relationships between some specific ions in edge water but

the complex influence of ions on the individual ion concentration is a much more interesting problem. Such studies allow to determine more accurately dependences of ions relationships in edge water. In our research, we used the methodology of multiple correlation-regression analysis, described in (Smagin & Gorlova, 2012). During the analysis, the general water mineralization and the concentrations of calcium and sodium ions were not taken into account since they are calculated values and, correspondingly, there is a functional relationship between them and other ions.

The correlation-regression analysis yielded the multiple linear regression with the resultant function:

$$C(c, b) = b_0 + b_1c_1 + b_2c_2 + \dots + b_i c_i, \quad (10)$$

where:

- C – sought concentration of ions (resultant value);
- $c_1 \dots c_i$ – known concentrations of ions (factors);
- $b_0 \dots b_i$ – angular coefficients.

Analytical studies were conducted in relation to the concentration of cations Ca^{2+} , Mg^{2+} and anions Cl^- , SO_4^{2-} , HCO_3^- . For each case, the concentration of one of the ions was a resultant value and the concentrations of other ions were effective factors.

Since the correlation-regression analysis is every time conducted for four factor loadings, the results of the calculations are shown in Table 3.

Table 3. General dataset of the correlation-regression analysis of the function

b_4	b_3	b_2	b_1	b_0
SE_4	SE_3	SE_2	SE_1	SE_0
R^2	SE_y	#N/D	#N/D	#N/D
f	df	#N/D	#N/D	#N/D
$SSreg$	$SSrem$	#N/D	#N/D	#N/D

where:

- $b_0 \dots b_4$ – regression parameters;
- $SE_0 \dots SE_4$ – root-mean square deviations for the parameters $b_0 \dots b_4$;
- R^2 – determination coefficient;
- SE_y – root-mean square deviation of the normal random variable $\hat{\epsilon}$;
- f – calculated value of the statistics F ;
- df – number of degrees of freedom ($45 - 5 = 40$ in our case);
- $SSreg$ – sum of squares caused by regression;
- $SSrem$ – sum of squares of the remainders.

The results of the correlation-regression analysis are shown below.

Table 4 shows the calculated parameters of chloride anions concentrations as the resultant value.

Table 4. Dataset of the correlation-regression analysis of chlorides function

3.203919895	3.854681721	-36.9692	-10.9815	90660.03
3.243203141	0.558324213	30.91987	16.22146	15007.2
0.731438151	16341.5352	#N/D	#N/D	#N/D
27.2353707	40	#N/D	#N/D	#N/D
29092362475	10681830914	#N/D	#N/D	#N/D

Based on the results in Table 3, the equation of multiple regression will have the form:

$$C_{Cl} = 90660.03 - 10.9815 C_{SO_4^{2-}} - 36.9692 C_{HCO_3^-} + 3.8547 C_{Ca^{2+}} + 3.2040 C_{Mg^{2+}} \quad (11)$$

The relatively high value of the determination coefficient of 0.7314 shows that there is a significant influence of the factor loadings onto the resultant one. Let us estimate the significance of the determination coefficient. Then, we will calculate the critical value F and assign the test of significance $F = 0.05$. Moreover, the number of degrees of freedom will be $5 - 1 = 4$ and $45 - 5 = 40$. Thus, $F_{critical}(0.05; 4; 40) = 2.606$.

Having compared the value $F_{critical}$ and calculated value of the statistics F , we can see that $F_{critical} = 2.606$ is many times greater than $F = 27.2354$. Thus, the determi-

nation coefficient F is much different from 0 which testifies to the existence of a regressional dependence.

Let us estimate the significance of the coefficients $b_0 \dots b_4$ with the help of some additional parameters. The calculated value of $t_{critical}$: $t_{critical}(0.025; 40) = 2.021$, where $0.025 = \alpha/2$ (α – test of significance, 0.05 in our case); $40 - df$ – number of degrees of freedom ($45 - 5 = 40$ in our case).

Table 5 shows the values of the statistics t for each coefficient.

Table 5. Values of the statistics t of the coefficients and their significance

b_i	b_4	b_3	b_2	b_1	b_0
$t = b_i / SE_i$	0.987887516	6.904020339	-1.19564	-0.67697	6.041102
Significance of the coefficient	no	yes	no	no	yes

The comparison of the value of statistics t for each coefficient $t_{critical}$ shows that only the values of the coefficients b_1 and b_4 are significant.

Based on the above, the regression dependence should be written in the form:

$$C_{Cl} = 90660.03 + 3.8547 C_{Ca^{2+}} \quad (12)$$

Figure 5 shows a graph of the calculated values of chlorides concentrations and a graph that was built in accordance with the values of field measurements.

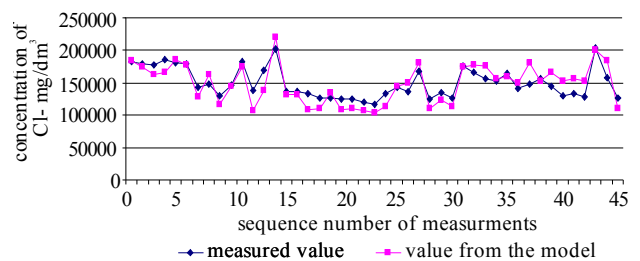


Figure 5. Comparison of model (calculated) values of chlorides concentrations and values of field measurements

The correlation coefficient between the model calculated values and values of field measurements is 0.85.

Table 6 shows the calculated parameters of sulphate ions concentrations as a resultant value.

Table 6. Dataset of the correlation-regression analysis of sulphates function

-0.00103	-0.00756	-0.01864	-0.77904	825.8836
0.001524	0.031791	0.007449	0.278997	152.9838
0.497887	158.3795	#N/D	#N/D	#N/D
9.915843	40	#N/D	#N/D	#N/D
994918.9	1003363	#N/D	#N/D	#N/D

Based on the results of Table 5, the equation of multiple regression will take the form:

$$C_{SO_4^{2-}} = 825.8836 - 0.77904 C_{HCO_3^-} - 0.01864 C_{Ca^{2+}} - 0.00756 C_{Mg^{2+}} - 0.00103 C_{Cl} \quad (13)$$

The value of the determination coefficient 0.4979 shows that factor loadings influence the resultant. The values of $F_{critical}$ (0.05; 4; 40) = 2.606 and $t_{critical}$ (0.025; 40) = 2.021 remain the same as the ones for chlorides. Having compared the values of $F_{critical}$ and the calculated value of the statistics F , we can see that $F_{critical}$ = 2.606 is lower than F = 9.9158. Thus, the determination coefficient F is much different from 0, which proves that there is a regression dependence.

Table 7 shows the values of the statistics t for each coefficient.

Table 7. Values of the statistics t of the coefficients and their significance

	b_i	b_4	b_3	b_2	b_1	b_0
$t = b_i / SE_i$		-0.67697	-0.23768	-2.50186	-2.79227	5.398504
Significance of the coefficient		no	no	yes	yes	yes

Based on the results of Table 6, the equation of multiple regression will take the form:

$$C_{SO_4^{2-}} = 825.8836 - 0.77904 C_{HCO_3^{3-}} - 0.01864 C_{Ca^{2+}}. \quad (14)$$

Figure 6 shows a graph of the calculated values of sulphates concentrations and a graph of the concentration values obtained from the actual measurements.

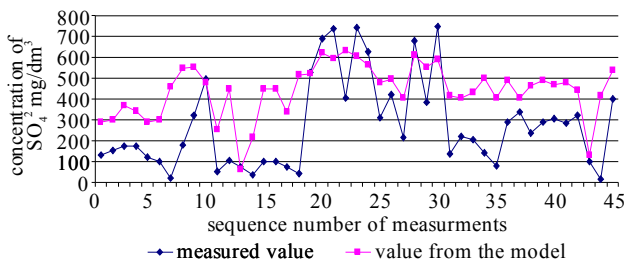


Figure 6. Comparison of model (calculated) values of sulphates concentrations and values of field measurements

The correlation coefficient between the model calculated values and values of the actual measurements is 0.70.

Table 8 shows the calculated parameters of the concentrations of the magnesium ions as a resultant value.

Table 8. Dataset of the correlation-regression analysis of the magnesium function

-0.01160396	1.194342201	-0.18664	0.007434	806.5938
0.03977138	1.503929207	0.78527	0.007525	991.4802
0.072090501	787.1442657	#N/D	#N/D	#N/D
0.776913058	40	#N/D	#N/D	#N/D
1925489.188	24783843.8	#N/D	#N/D	#N/D

The insignificant value of the determination coefficient 0.072 shows that there is no influence of the factor loadings onto the resultant. Let us determine the significance of the determination coefficient. Having compared the values of $F_{critical}$ and the calculated value of the statistics F , we can see that $F_{critical}$ = 2.606 is greater than

F = 0.7769. Thus, the determination coefficient F is slightly different from 0 and this shows that there is no regression dependence.

Table 9 presents the calculated parameters of calcium ions concentrations as a resultant.

Table 9. Dataset of the correlation-regression analysis of calcium function

0.14105449	-0.183013	-3.31868	-7.26034	-2762.29
0.02043077	0.6272578	5.996609	2.901973	3945.853
0.755882	3126.0221	#N/D	#N/D	#N/D
30.9637968	40	#N/D	#N/D	#N/D
1210314635	390880564	#N/D	#N/D	#N/D

Based on the results of Table 9, the equation of the multiple regression will be:

$$C_{Ca^{2+}} = 0.141 C_{Cl^-} - 0.1830 C_{Mg^{2+}} - 3.3187 C_{HCO_3^{3-}} - 7.26034 C_{SO_4^{2-}} - 2762.29. \quad (15)$$

The value of the determination coefficient 0.7559 shows that there is an influence of the factor loadings onto the resultant. The values of $F_{critical}$ (0.05; 4; 40) = 2.606 and $t_{critical}$ (0.025; 40) = 2.021 remain the same as the ones for other ions. Having compared the values of $F_{critical}$ and the calculated value of the statistics F , we can see that $F_{critical}$ = 2.606 is lower than F = 30.9638. Thus, the determination coefficient F is much different from 0 and this testifies to the presence of a regression dependence.

Table 10 shows the values of the statistics t for each coefficient.

Table 10. Values of the statistics t of the coefficients and their significance

	b_i	b_4	b_3	b_2	b_1	b_0
$t = b_i / SE_i$		6.90402034	-0.291767	-0.55343	-2.50186	0.70005
Significance of the coefficient		yes	no	no	yes	no

Based on the results of Table 10, the equation of the multiple regression will be:

$$C_{Ca^{2+}} = 0.141 C_{Cl^-} - 7.26034 C_{SO_4^{2-}}. \quad (16)$$

Figure 7 shows a graph of the calculated values of calcium concentrations and a graph of the concentrations values obtained via actual measurements.

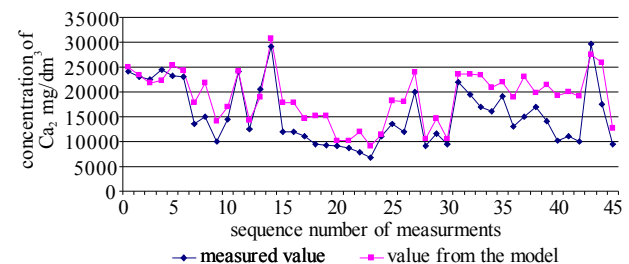


Figure 7. Comparison of the model (calculated) values of calcium concentrations and values of the actual measurements

The Pearson's correlation coefficient between the data of the actual measurements and the model data is 0.87.

Table 11 shows the calculated parameters of calcium ions concentrations as a resultant.

Table 11. Dataset of the correlation-regression analysis of hydrocarbonates function

-0.00229	-0.00093	0.012996	-0.20939	333.9146
0.004137	0.000781	0.016365	0.07499	89.92467
0.204179	82.11074	#N/D	#N/D	#N/D
2.565641	40	#N/D	#N/D	#N/D
69191.99	269686.9	#N/D	#N/D	#N/D

The insignificant value of the determination coefficient 0.072 shows that there is no influence of the factor loadings onto the resultant. Let us determine the significance of the determination coefficient. Having compared the values of F critical and the calculated value of the statistics F , we can see that $F_{critical} = 2.606$ is greater than $F = 2.5656$. Thus, the determination coefficient F is slightly different from 0 and this testifies to the absence of a regression dependence.

4. CONCLUSIONS

Thus, based on the study results, we found that the regression dependences between separate ions of salts are observed in edge water with high salts concentrations.

The established dependences between ions concentrations in edge water allow to significantly reduce complexity of the analytical laboratory studies since they provide a possibility to calculate the content of macrocomponents depending on the water mineralization. Moreover, the general mineralization can be determined

ABSTRACT (IN UKRAINIAN)

Мета. Вивчення особливостей формування фізичного та хімічного складу сильно мінералізованих пластових вод нафтових і газових родовищ.

Методика. Кореляційні зв'язки між макроіонами крайових вод були створені шляхом розрахунку коефіцієнта кореляції Пірсона. Для визначення комплексного впливу концентрації декількох іонів від концентрації одного з них була використана методика множинного кореляційного аналізу регресії.

Результати. Емпіричні залежності між концентраціями окремих іонів сильно мінералізованих пластових вод, що були отримані у результаті проведених досліджень.

Наукова новизна. Визначені залежності між загальною мінералізацією води й складом макроіонів, а також встановлено комплексний вплив декількох іонів на концентрацію одного з них.

Практична значимість. Виявленні залежності можуть бути використані для проведення лабораторних аналізів крайових вод.

Ключові слова: крайові води, мінералізація, критерій Пірсона, аніони, катіони, кореляційно-регресійна залежність

ABSTRACT (IN RUSSIAN)

Цель. Изучение особенностей формирования физического и химического состава сильно минерализованных пластовых вод нефтяных и газовых месторождений.

Методика. Корреляционные связи между макроионами краевых вод были созданы путем расчета коэффициента корреляции Пирсона. Для определения комплексного влияния концентрации нескольких ионов от концентрации одного из них была использована методика множественного корреляционного анализа регрессии.

Результаты. Эмпирические зависимости между концентрациями отдельных ионов сильно минерализованных пластовых вод, полученные в результате проведенных исследований.

Научная новизна. Определены зависимости между общей минерализацией воды и составом макроионов, а также установлено комплексное воздействие нескольких ионов на концентрацию одного из них.

with the help of the TDS (total dissolved solids) meters and macrocomponents can be calculated using simple software. It should be noted that the analytical study methods are more accurate, while the proposed calculation method can be used to carry out express analysis of edge waters, particularly in field conditions.

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Практическая значимость. Выявленные зависимости могут быть использованы для проведения лабораторных анализов краевых вод.

Ключевые слова: *краевые воды, минерализация, критерий Пирсона, анионы, катионы, корреляционно-регрессионная зависимость*

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