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## Comparative study of the effects on the EEG of drinking monotherapy with Naftussya water and therapy supplemented with "Myroslava" and "Khrystyna" mineral waters

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### Abstract

**Background.** Earlier we showed that the newly created sulfate-chloride sodium-magnesium drinking mineral waters of Truskavets' spa have favorable effects on metabolism and neuroendocrine-immune complex of patients with their dysfunction. This report analyzes the effect of balneotherapy on the parameters of the electroencephalogram of the same contingent of patients. **Materials and Methods.** The object of clinical-physiological observation were 34 men aged 23-70 years, who underwent rehabilitation treatment of chronic cholecystitis and pyelonephritis in remission in the Truskavets' spa. The examination was performed twice, before and after a 7-10-day course of balneotherapy. All patients received bioactive water Naftussya, however, 11 men additionally drank water "Khrystyna", and the other 11 men - water "Myroslava". The subject of the study were the parameters of the electroencephalogram. **Results.** The complex balneotherapy by interval use of sulfate-chloride sodium-magnesium mineral waters with Naftussya water causes significant changes in the constellation of EEG parameters, which are different from the effects of Naftussya water monotherapy. Own effects of mineral waters are estimated by modeling. Two patterns of neurotropic effects have been identified - activating and inhibitory. In general, the neuromodulating effects are physiologically favorable. **Conclusion.** The newly created sulfate-chloride sodium-magnesium drinking mineral waters of Truskavets' spa have favorable neuromodulating effects on patients with chronic cholecystitis and pyelonephritis.

**Keywords:** sulfate-chloride sodium-magnesium drinking mineral waters, Truskavets' spa, EEG parameters.

## INRODUCTION

Earlier we showed that the newly created sulfate-chloride sodium-magnesium drinking mineral waters of Truskavets' spa have favorable effects on metabolism and neuroendocrine-immune complex of patients with their dysfunction [2]. Given the close relationship between EEG parameters and endocrine and immune systems parameters [1,4-6], as well as between their changes under the influence of balneotherapy [1,7-11], the aim of this study was to analyze the effects of mineral water on EEG parameters of the same patients.

## MATERIALS AND METHODS

The object of clinical-physiological observation were 34 men aged 23-70 years, who underwent rehabilitation treatment in the Truskavets' spa of chronic cholecystitis and pyelonephritis in remission with of neuroendocrine-immune complex dysfunction. The examination was performed twice, before and after a 7-10-day course of balneotherapy. All patients received bioactive water Naftussya (3 ml/kg one hour before meals three times a day), however, 11 men in half an hour additionally drank water "Khrystyna", and the other 11 men - water "Myroslava" in the same dose.

We recorded simultaneously with HRV EEG a hardware-software complex "NeuroCom Standard" (KhAI MEDICA, Kharkiv) monopolar in 16 loci (Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2) by 10-20 international system, with the reference electrodes A and Ref tassels on the ears. The duration of the epoch was 25 sec. Among the options considered the average EEG amplitude ( $\mu\text{V}$ ), average frequency (Hz), frequency deviation (Hz) as well as absolute ( $\mu\text{V}^2/\text{Hz}$ ) and relative (%) power spectrum density (PSD) of basic rhythms:  $\beta$  ( $35\div 13$  Hz),  $\alpha$  ( $13\div 8$  Hz),  $\theta$  ( $8\div 4$  Hz) and  $\delta$  ( $4\div 0,5$  Hz) in all loci, according to the instructions of the device. In addition, calculated Laterality Index (LI) for PSD each Rhythm using formula:

$$\text{LI, \%} = \Sigma [200 \cdot (\text{Right} - \text{Left}) / (\text{Right} + \text{Left})] / 8.$$

We calculated also for each locus EEG Shannon's CE entropy (h) of normalized PSD using Popovych's IL formula [1]:

$$h_{\text{EEG}} = - [\text{PSD}\alpha \cdot \log_2 \text{PSD}\alpha + \text{PSD}\beta \cdot \log_2 \text{PSD}\beta + \text{PSD}\theta \cdot \log_2 \text{PSD}\theta + \text{PSD}\delta \cdot \log_2 \text{PSD}\delta] / \log_2 4$$

Normal (reference) values of variables are taken from the database of the Truskavetsian School of Balneology.

## RESULTS AND DISCUSSION

Following the accepted algorithm [2], the method of discriminant analysis [3] revealed 30 EEG parameters, according to which the conditions of patients before and after the two balneotherapy regimens differ significantly. Characteristic were 4 parameters of **beta**-rhythm, 6 parameters of **alpha**- and **theta**-rhythm and 8 parameters of **delta**-rhythm, as well as the **entropy** of PSD in 6 loci (Tables 1 and 3).

**Table 1. Summary of the analysis of discriminant functions in relation to the parameters of EEG**

Step 30, N of vars in model: 30; Grouping: 3 grps; Wilks'  $\Lambda$ : 0,057; approx.  $F_{(61)}=3,8$ ;  $p<10^{-6}$

Variables currently in the model	Groups (n) and Means $\pm$ SE			Parameters of Wilks' Statistics					Norm Cv/ $\sigma$ (122)
	After Naftus-sya (12)	After Salt Waters and N (22)	Before therapy (34)	Wilks' $\Lambda$	Partial $\Lambda$	F-remove (2,36)	p-level	Tolerance	
Laterality $\beta$ , %	-33 10	-4 4	-3 5	0,086	0,666	9,03	0,001	0,179	-6 28
F4- $\beta$ PSD, $\mu V^2/Hz$	68 11	92 12	86 9	0,061	0,938	1,19	0,317	0,101	73 0,612
T4- $\beta$ PSD, %	33,6 4,7	37,3 4,6	29,0 2,4	0,071	0,798	4,56	0,017	0,111	27,9 0,591
Fp2- $\beta$ PSD, $\mu V^2/Hz$	50 7	74 10	74 8	0,061	0,936	1,23	0,305	0,232	61 0,629
Laterality $\alpha$ , %	-23 9	-18 5	-1 6	0,066	0,858	2,97	0,064	0,096	-4 27
T4- $\alpha$ PSD, %	23,0 3,2	32,6 3,9	28,0 2,9	0,058	0,987	0,23	0,794	0,069	29,2 0,628
F8- $\alpha$ PSD, $\mu V^2/Hz$	37 13	23 2	37 4	0,063	0,909	1,80	0,179	0,267	40 0,957
F4- $\alpha$ PSD, %	22,0 3,8	31,5 3,1	31,4 3,4	0,120	0,475	19,9	$10^{-6}$	0,031	32,7 0,564
P3- $\alpha$ PSD, %	37,7 5,5	49,5 3,8	42,1 3,6	0,077	0,737	6,44	0,004	0,032	40,8 0,480
C3- $\alpha$ PSD, %	30,1 4,8	38,9 3,4	35,5 3,2	0,071	0,803	4,43	0,019	0,057	35,3 0,510
Laterality $\theta$ , %	-24 10	-35 10	-4 7	0,119	0,478	19,7	$10^{-5}$	0,036	-3 32
T4- $\theta$ PSD, $\mu V^2/Hz$	22 4	19 3	34 7	0,079	0,724	6,85	0,003	0,032	32 2,582
F7- $\theta$ PSD, %	9,8 1,0	8,8 1,3	7,1 0,7	0,127	0,450	22,0	$10^{-6}$	0,055	7,9 0,568
T4- $\theta$ PSD, %	9,1 0,8	6,4 0,7	9,5 1,2	0,101	0,565	13,86	$10^{-4}$	0,016	8,7 0,539
Fp2- $\theta$ PSD, %	8,9 0,8	6,7 1,3	9,7 1,5	0,095	0,600	12,0	$10^{-4}$	0,028	8,3 0,588
Fp2- $\theta$ PSD, $\mu V^2/Hz$	18 3	20 4	29 7	0,083	0,690	8,08	0,001	0,033	25 1,186
Deviation $\delta$ , Hz	0,71 0,10	0,57 0,04	0,73 0,05	0,067	0,846	3,27	0,050	0,490	0,66 0,405
T6- $\delta$ PSD, $\mu V^2/Hz$	53 11	279 136	174 73	0,124	0,458	21,3	$10^{-6}$	0,006	276 4,53
T5- $\delta$ PSD, $\mu V^2/Hz$	85 21	234 111	395 200	0,078	0,735	6,49	0,004	0,084	174 3,737
F7- $\delta$ PSD, $\mu V^2/Hz$	84 26	870 621	342 169	0,095	0,602	11,9	$10^{-4}$	0,016	319 4,542
F8- $\delta$ PSD, %	50,2 8,8	28,3 7,3	38,8 4,7	0,074	0,770	5,37	0,009	0,183	38,3 0,700
C4- $\delta$ PSD, %	34,8 6,5	22,9 4,0	28,6 3,5	0,066	0,865	2,81	0,073	0,107	29,9 0,617
O2- $\delta$ PSD, $\mu V^2/Hz$	104 19	624 338	272 117	0,062	0,913	1,72	0,193	0,086	181 2,438
P3- $\delta$ PSD, %	27,5	19,8	27,3	0,082	0,695	7,89	0,001	0,036	26,5

<b>%</b>	4,9	3,4	3,3						0,672
<b>Entropy F7</b>	0,851 0,024	0,724 0,054	0,704 0,039	0,060	0,956	0,83	0,446	0,122	0,751 0,282
<b>Entropy Fp2</b>	0,797 0,036	0,705 0,048	0,817 0,024	<b>0,202</b>	<b>0,282</b>	<b>45,9</b>	<b>10<sup>-6</sup></b>	<b>0,021</b>	0,799 0,180
<b>Entropy T4</b>	0,843 0,029	0,736 0,030	0,819 0,022	<b>0,131</b>	<b>0,434</b>	<b>23,5</b>	<b>10<sup>-6</sup></b>	<b>0,029</b>	0,790 0,215
<b>Entropy O2</b>	0,798 0,027	0,669 0,037	0,769 0,028	<b>0,082</b>	<b>0,698</b>	<b>7,77</b>	<b>0,002</b>	<b>0,106</b>	0,727 0,242
<b>Entropy T6</b>	0,834 0,026	0,710 0,046	0,790 0,031	<b>0,069</b>	<b>0,826</b>	<b>3,79</b>	<b>0,032</b>	<b>0,108</b>	0,761 0,249
<b>Entropy P3</b>	0,851 0,032	0,771 0,025	0,797 0,024	<b>0,068</b>	<b>0,834</b>	<b>3,57</b>	<b>0,038</b>	<b>0,098</b>	0,804 0,155

Note. In each column, the first line is the average, the second – SE for variables and Cv or *SD* for Norm.

A number of variables despite their recognizable properties, were outside the discriminant model, apparently due to duplication and/or redundancy of information (Table 2).

**Table 2. EEGs parameters not included in the model**

Variables currently in the model	Groups (n) and Means±SE			Parameters of Wilks' Statistics					Norm Cv/σ (122)
	After Naftus-sya (12)	After Salt Waters and N (22)	Before therapy (34)	Wilks' Λ	Partial Λ	F to enter	p-level	Tolerance	
<b>F8-β PSD, %</b>	23,9 4,9	39,0 5,1	29,9 3,5	0,057	0,995	0,09	0,912	0,067	28,7 0,702
<b>F8-θ PSD, μV<sup>2</sup>/Hz</b>	23 5	11 2	22 5	0,056	0,985	0,26	0,772	0,252	19 1,791
<b>O2-θ PSD, %</b>	7,2 0,8	5,1 0,6	6,1 0,7	0,057	0,996	0,07	0,928	0,255	6,0 0,603
<b>Entropy T5</b>	0,835 0,028	0,770 0,041	0,744 0,033	0,057	0,998	0,03	0,969	0,170	0,778 0,211

The identifying information contained in the 30 discriminant variables is condensed into two roots. The major root contains 90% of discriminatory opportunities ( $r^*=0,944$ ; Wilks'  $\Lambda=0,057$ ;  $\chi^2_{(60)}=145$ ;  $p<10^{-6}$ ), while minor root 10% only ( $r^*=0,689$ ; Wilks'  $\Lambda=0,526$ ;  $\chi^2_{(29)}=32$ ;  $p=0,299$ ).

**Table 3. Summary of stepwise analysis of discriminant variables ranked by criterion Λ**

Variables currently in the model	F to enter	p-level	Λ	F-value	p-level
<b>Laterality β, %</b>	<b>6,28</b>	<b>0,003</b>	<b>0,84</b>	<b>6,28</b>	<b>0,003</b>
<b>Laterality θ, %</b>	<b>4,02</b>	<b>0,023</b>	<b>0,74</b>	<b>5,09</b>	<b>0,001</b>
<b>Entropy F7</b>	2,83	0,067	0,68	4,41	10 <sup>-3</sup>
<b>Entropy Fp2</b>	<b>3,31</b>	<b>0,043</b>	<b>0,62</b>	<b>4,23</b>	10 <sup>-3</sup>
<b>T4-α PSD, %</b>	2,00	0,144	0,58	3,83	10 <sup>-3</sup>
<b>Entropy T4</b>	2,37	0,102	0,54	3,65	10 <sup>-3</sup>
<b>T6-δ PSD, μV<sup>2</sup>/Hz</b>	2,87	0,065	0,49	3,62	10 <sup>-4</sup>
<b>T4-θ PSD, μV<sup>2</sup>/Hz</b>	1,96	0,150	0,46	3,46	10 <sup>-4</sup>
<b>F8-α PSD, μV<sup>2</sup>/Hz</b>	2,25	0,115	0,42	3,38	10 <sup>-4</sup>
<b>F4-α PSD, %</b>	1,72	0,188	0,40	3,25	10 <sup>-4</sup>
<b>P3-α PSD, %</b>	3,02	0,057	0,36	3,32	10 <sup>-4</sup>
<b>T5-δ PSD, μV<sup>2</sup>/Hz</b>	<b>3,22</b>	<b>0,048</b>	<b>0,32</b>	<b>3,43</b>	10 <sup>-5</sup>

<b>F7-<math>\theta</math> PSD, %</b>	2,08	0,135	0,30	3,38	$10^{-5}$
<b>Entropy O2</b>	2,78	0,071	0,27	3,43	$10^{-5}$
<b>T4-<math>\theta</math> PSD, %</b>	2,26	0,115	0,25	3,43	$10^{-5}$
<b>F7-<math>\delta</math> PSD, <math>\mu V^2/Hz</math></b>	5,41	0,007	0,20	3,80	$10^{-6}$
<b>F4-<math>\beta</math> PSD, <math>\mu V^2/Hz</math></b>	3,21	0,049	0,18	3,91	$10^{-6}$
<b>Fp2-<math>\theta</math> PSD, %</b>	1,63	0,207	0,17	3,82	$10^{-6}$
<b>Laterality <math>\alpha</math>, %</b>	2,22	0,120	0,15	3,83	$10^{-6}$
<b>Fp2-<math>\theta</math> PSD, <math>\mu V^2/Hz</math></b>	2,13	0,131	0,14	3,82	$10^{-6}$
<b>Deviation <math>\delta</math>, Hz</b>	2,06	0,139	0,13	3,82	$10^{-6}$
<b>F8-<math>\delta</math> PSD, %</b>	1,97	0,152	0,12	3,80	$10^{-6}$
<b>C4-<math>\delta</math> PSD, %</b>	1,77	0,183	0,11	3,77	$10^{-6}$
<b>O2-<math>\delta</math> PSD, <math>\mu V^2/Hz</math></b>	2,61	0,085	0,10	3,85	$10^{-6}$
<b>P3-<math>\delta</math> PSD, %</b>	1,34	0,272	0,09	3,78	$10^{-6}$
<b>Entropy T6</b>	2,29	0,114	0,08	3,83	$10^{-6}$
<b>Entropy P3</b>	1,13	0,334	0,08	3,74	$10^{-6}$
<b>T4-<math>\beta</math> PSD, %</b>	1,05	0,359	0,07	3,65	$10^{-6}$
<b>C3-<math>\alpha</math> PSD, %</b>	3,86	0,030	0,06	3,89	$10^{-6}$
<b>Fp2-<math>\beta</math> PSD, <math>\mu V^2/Hz</math></b>	1,23	0,305	0,06	3,83	$10^{-6}$

Calculating the values of discriminant roots for each patient by the raw coefficients and the constant (Table 4) allows visualization of each patient in the information space of roots.

**Table 4. Standardized and raw coefficients and constants for discriminant EEG variables**

Coefficients Variables	Standardized		Raw	
	Root 1	Root 2	Root 1	Root 2
<b>Laterality <math>\beta</math>, %</b>	1,374	-0,613	0,0550	-0,0245
<b>Laterality <math>\theta</math>, %</b>	-3,999	0,492	-0,1119	0,0138
<b>Entropy F7</b>	-0,591	-0,314	-3,1466	-1,6701
<b>Entropy Fp2</b>	6,220	-0,378	42,538	-2,5875
<b>T4-<math>\alpha</math> PSD, %</b>	-0,174	-0,578	-0,0122	-0,0404
<b>Entropy T4</b>	-4,676	0,530	-40,737	4,6211
<b>T6-<math>\delta</math> PSD, <math>\mu V^2/Hz</math></b>	10,024	0,449	0,0252	0,0011
<b>T4-<math>\theta</math> PSD, <math>\mu V^2/Hz</math></b>	-3,112	0,440	-0,1137	0,0161
<b>F8-<math>\alpha</math> PSD, <math>\mu V^2/Hz</math></b>	0,083	0,840	0,0034	0,0350
<b>F4-<math>\alpha</math> PSD, %</b>	4,266	1,032	0,2782	0,0673
<b>P3-<math>\alpha</math> PSD, %</b>	-3,000	-0,717	-0,1691	-0,0404
<b>T5-<math>\delta</math> PSD, <math>\mu V^2/Hz</math></b>	-1,756	0,903	-0,0022	0,0011
<b>F7-<math>\theta</math> PSD, %</b>	-3,351	-0,172	-0,8149	-0,0419
<b>Entropy O2</b>	1,788	0,087	13,073	0,6355
<b>T4-<math>\theta</math> PSD, %</b>	5,478	-1,528	1,1257	-0,3139
<b>F7-<math>\delta</math> PSD, <math>\mu V^2/Hz</math></b>	-5,196	-1,160	-0,0036	-0,0008
<b>F4-<math>\beta</math> PSD, <math>\mu V^2/Hz</math></b>	-0,261	-1,081	-0,0057	-0,0237
<b>Fp2-<math>\theta</math> PSD, %</b>	-4,001	0,581	-0,6332	0,0920
<b>Laterality <math>\alpha</math>, %</b>	1,280	-0,107	0,0480	-0,0040
<b>Fp2-<math>\theta</math> PSD, <math>\mu V^2/Hz</math></b>	3,187	0,695	0,1170	0,0255
<b>Deviation <math>\delta</math>, Hz</b>	-0,575	0,198	-2,3259	0,8004
<b>F8-<math>\delta</math> PSD, %</b>	-1,147	0,423	-0,0429	0,0159
<b>C4-<math>\delta</math> PSD, %</b>	1,024	-0,824	0,0565	-0,0454
<b>O2-<math>\delta</math> PSD, <math>\mu V^2/Hz</math></b>	0,121	-1,455	0,0001	-0,0017
<b>P3-<math>\delta</math> PSD, %</b>	-3,103	0,037	-0,1946	0,0023
<b>Entropy T6</b>	1,313	-0,371	8,3683	-2,3617
<b>Entropy P3</b>	-1,378	0,050	-12,129	0,4444

<b>T4-β PSD, %</b>	-1,370	-0,549	-0,0913	-0,0366
<b>C3-α PSD, %</b>	-1,903	-0,704	-0,1222	-0,0452
<b>Fp2-β PSD, μV<sup>2</sup>/Hz</b>	0,487	0,366	0,0126	0,0095
	<b>Constants</b>		7,567	5,967
	<b>Eigenvalues</b>		8,22	0,90
<b>Cumulative Proportion</b>			0,901	1

The localization of the cluster of patients who received only **Naftussya** water in the extreme left zone of the first root axis (Fig. 1) reflects the maximum decrease in the initial parameters that are **positively** related to the root, as well as the maximum increase **inversely** correlated parameters (Table 5). Recall that a negative value of the Laterality Index indicates a left shift of symmetry. In contrast, in patients receiving **complex balneotherapy**, these EEG parameters deviated from the initial to a much lesser extent or remained unchanged.

On the other hand, these patients are characterized by reduced or minimal for sample EEG parameters that correlate **positively** with the second root, and correspondingly increased or maximum for sample EEG parameters that correlate **negatively** with it, which is visualized by localization of the cluster in the lower root axis.

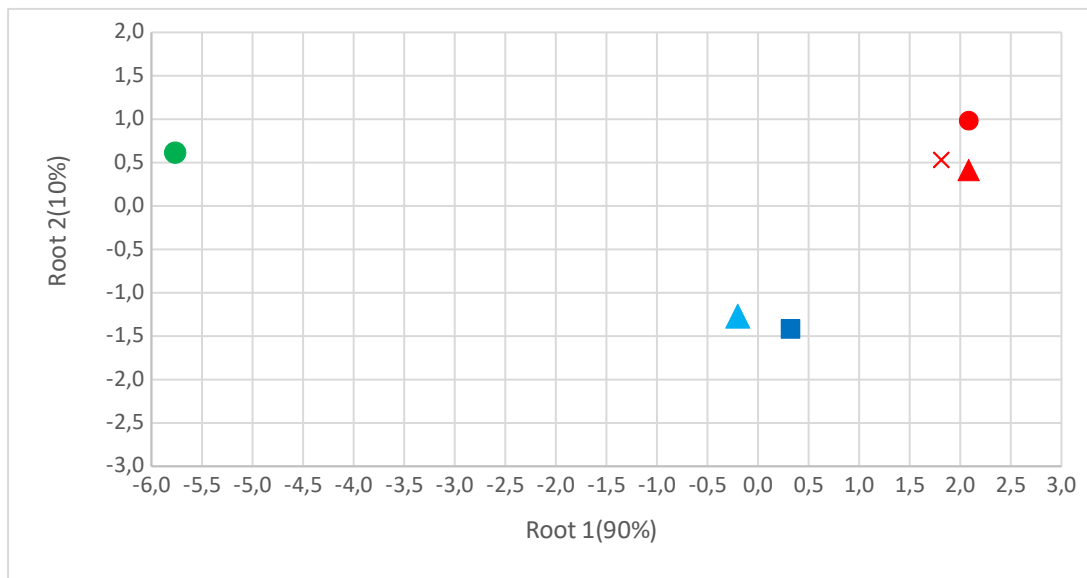
**Table 5. Correlations between EEGs variables and roots, centroids of clusters and Z-scores of variables**

Variables	Correlations Variables-Roots		After Naftussya (12)	After Salt Waters and N (22)	Before therapy (34)
	Root 1	Root 2			
<b>Root 1 (90%)</b>	<b>Root 1</b>	<b>Root 2</b>	<b>-5,77</b>	+0,06	+2,00
<b>Laterality β</b>	<b>0,149</b>	-0,112	<b>-0,95</b>	+0,08	+0,10
<b>Laterality α</b>	<b>0,098</b>	0,144	<b>-0,71</b>	-0,52	+0,12
<b>F4-α PSDr</b>	<b>0,076</b>	-0,065	<b>-0,58</b>	-0,06	-0,07
<b>Fp2-β PSDa</b>	<b>0,075</b>	-0,061	<b>-0,26</b>	+0,35	+0,35
<b>Fp2-θ PSDa</b>	<b>0,048</b>	0,079	<b>-0,23</b>	-0,17	+0,14
<b>T5-δ PSDa</b>	<b>0,047</b>	0,032	<b>-0,14</b>	+0,09	+0,34
<b>Entropy F7</b>	<b>-0,096</b>	0,039	<b>+0,47</b>	-0,13	-0,22
<b>Entropy T5</b>			<b>+0,35</b>	-0,05	-0,20
<b>F7-θ PSDr</b>	<b>-0,077</b>	-0,082	<b>+0,51</b>	+0,29	-0,11
<b>Root 2 (10%)</b>	<b>Root 1</b>	<b>Root 2</b>	+0,61	<b>-1,34</b>	+0,65
<b>Laterality θ</b>	0,063	<b>0,240</b>	-0,66	<b>-0,98</b>	-0,04
<b>Entropy Fp2</b>	0,012	<b>0,256</b>	-0,02	<b>-0,66</b>	+0,13
<b>T4-θ PSDr</b>	0,006	<b>0,215</b>	+0,08	<b>-0,49</b>	+0,17
<b>F8-α PSDa</b>	-0,007	<b>0,201</b>	-0,07	<b>-0,44</b>	-0,08
<b>Entropy O2</b>	-0,031	<b>0,277</b>	+0,40	<b>-0,32</b>	+0,24
<b>Entropy T4</b>	-0,032	<b>0,272</b>	+0,31	<b>-0,32</b>	+0,17
<b>Deviation δ</b>	0,007	<b>0,218</b>	+0,17	<b>-0,34</b>	+0,26
<b>Entropy T6</b>	-0,039	<b>0,206</b>	+0,39	<b>-0,27</b>	+0,15
<b>F8-δ PSDr</b>	-0,056	<b>0,180</b>	+0,45	<b>-0,37</b>	+0,02
<b>P3-δ PSDr</b>	-0,005	<b>0,166</b>	+0,06	<b>-0,38</b>	+0,04
<b>Fp2-θ PSDr</b>	0,012	<b>0,157</b>	+0,13	<b>-0,34</b>	+0,29
<b>T4-θ PSDa</b>	0,049	<b>0,155</b>	-0,12	<b>-0,16</b>	+0,03
<b>C4-δ PSDr</b>	-0,045	<b>0,145</b>	+0,27	<b>-0,38</b>	-0,07
<b>O2-θ PSDr</b>			+0,32	<b>-0,25</b>	+0,03
<b>F8-θ PSDa</b>			+0,11	<b>-0,24</b>	+0,08
<b>Entropy P3</b>	-0,061	<b>0,127</b>	+0,38	<b>-0,27</b>	-0,06
<b>O2-δ PSDa</b>	0,028	<b>-0,167</b>	-0,18	<b>+1,00</b>	+0,21
<b>T4-β PSDr</b>	-0,034	<b>-0,164</b>	+0,35	<b>+0,58</b>	+0,07
<b>F8-β PSDr</b>			-0,24	<b>+0,51</b>	+0,06
<b>P3-α PSDr</b>	0,034	<b>-0,171</b>	-0,15	<b>+0,45</b>	+0,07
<b>F4-β PSDa</b>	0,050	<b>-0,085</b>	-0,11	<b>+0,43</b>	+0,30
<b>F7-δ PSDa</b>	0,025	<b>-0,145</b>	-0,16	<b>+0,38</b>	+0,02
<b>T4-α PSDr</b>	0,046	<b>-0,147</b>	-0,34	<b>+0,19</b>	-0,07
<b>C3-α PSDr</b>	0,045	<b>-0,111</b>	-0,29	<b>+0,20</b>	+0,01
<b>T6-δ PSDa</b>	0,040	<b>-0,123</b>	-0,18	<b>0,00</b>	-0,08

**Fig. 1. Scattering of individual values of the first and second EEG discriminant roots of patients before (circles) and after the course of drinking only water Naftussya (triangles) and in combination with water "Myroslava" or "Khrystyna" (rhombuses)**

Fig. 2 illustrates that the integrated initial state of all three groups of patients was almost the

same as the effect on the discriminant EEG variables of both sulfate-chloride sodium-magnesium mineral waters.



**Fig. 2.** Mean values ( $M \pm SD$ ) of the first and second discriminant EEG roots of patients before (red fill) and after the course of drinking only water "Naftussya" (circle) and in combination with water "Myroslava" (triangle) or "Khrystyna" (square)

The visual impression of a clear demarcation of the three clusters in the information field of the two roots is documented by calculating the distances of Mahalanobis (Table 6).

**Table 6.** Squares of Mahalanobis distances between clusters (above the diagonal) and F-criteria ( $df=30,3$ ) and p-levels (below the diagonal)

Clusters	Before therapy	After Naftussya	After SW&N
Before therapy	0	60	7,7
After Naftussya	9,9 $10^{-6}$	0	38
After SW&N	1,91 0,033	5,4 $10^{-5}$	0

Selected discriminant variables were used to identify the affiliation of a patient to a particular cluster. This goal of discriminant analysis is realized with the help of classification functions (Table 7).

**Table 7.** Coefficients and constants of classification functions

Clusters	Before therapy	After Naftussya	After Salt W&N
Variables	$p=,500$	$p=,176$	$p=,324$
Laterality $\beta$ , %	-0,914	-1,340	-0,972
Laterality $\theta$ , %	-0,046	0,822	0,143
Entropy F7	233,3	257,8	242,8
Entropy Fp2	-83,74	-413,79	-160,9
T4- $\alpha$ PSD, %	2,086	2,182	2,190

<b>Entropy T4</b>	-353,5	-37,51	-283,9
<b>T6-<math>\delta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	-0,226	-0,422	-0,277
<b>T4-<math>\theta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	-0,583	0,299	-0,395
<b>F8-<math>\alpha</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	0,032	0,004	-0,045
<b>F4-<math>\alpha</math> PSD, %</b>	-0,515	-2,678	-1,188
<b>P3-<math>\alpha</math> PSD, %</b>	6,436	7,750	6,844
<b>T5-<math>\delta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	0,037	0,055	0,040
<b>F7-<math>\theta</math> PSD, %</b>	-4,860	1,466	-3,200
<b>Entropy O2</b>	386,6	285,1	360,0
<b>T4-<math>\theta</math> PSD, %</b>	15,31	6,583	13,76
<b>F7-<math>\delta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	0,054	0,081	0,062
<b>F4-<math>\beta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	0,976	1,021	1,035
<b>Fp2-<math>\theta</math> PSD, %</b>	2,844	7,755	3,886
<b>Laterality <math>\alpha</math>, %</b>	1,108	0,735	1,023
<b>Fp2-<math>\theta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	-2,362	-3,270	-2,639
<b>Deviation <math>\delta</math>, Hz</b>	11,68	29,70	14,59
<b>F8-<math>\delta</math> PSD, %</b>	0,296	0,628	0,347
<b>C4-<math>\delta</math> PSD, %</b>	2,239	1,802	2,220
<b>O2-<math>\delta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	0,069	0,068	0,072
<b>P3-<math>\delta</math> PSD, %</b>	6,638	8,148	7,010
<b>Entropy T6</b>	-135,2	-200,0	-146,7
<b>Entropy P3</b>	757,5	851,7	780,1
<b>T4-<math>\beta</math> PSD, %</b>	5,517	6,227	5,766
<b>C3-<math>\alpha</math> PSD, %</b>	5,831	6,781	6,158
<b>Fp2-<math>\beta</math> PSD, <math>\mu\text{V}^2/\text{Hz}</math></b>	-0,295	-0,392	-0,338
<b>Constants</b>	-838,8	-913,5	-864,5

The accuracy of the classification is 91,2% (Table 8).

**Table 8. Classification matrix**

Rows: observed classifications; columns: projected classifications

	Percent Correct	<b>Before therap y</b>	<b>After Naftussya</b>	<b>After Salt W&amp;N</b>
Groups		p=,500	p=,176	p=,324
<b>Before therapy</b>	82,4	<b>28</b>	0	6
<b>After Naftussya</b>	100	0	<b>12</b>	0
<b>After Salt W&amp;N</b>	100	0	0	<b>22</b>
<b>Total</b>	91,2	28	12	28

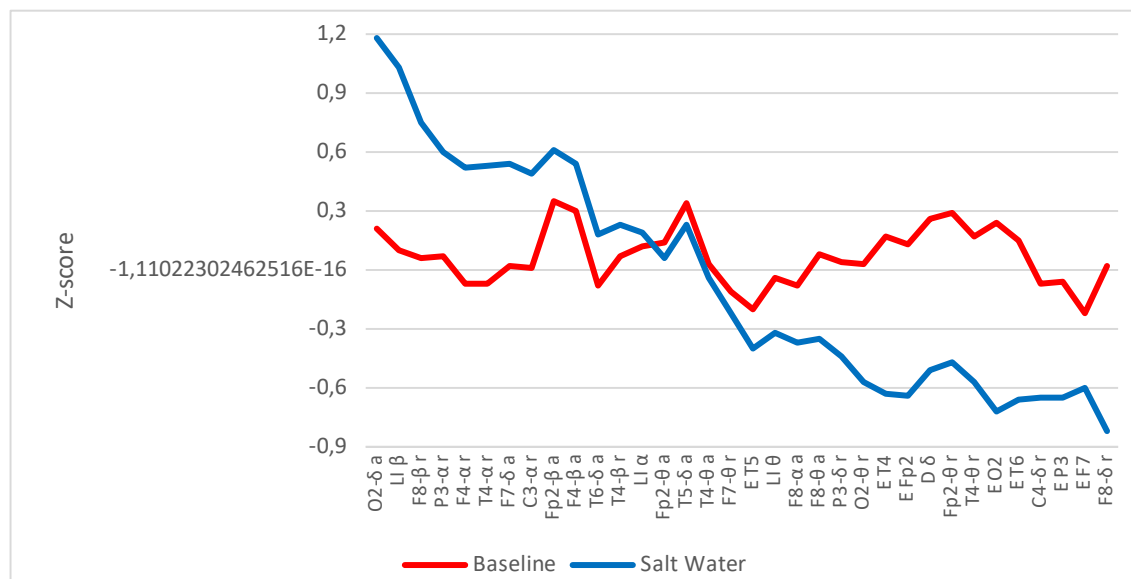
Thus, we have shown that complex balneotherapy by interval use of sulfate-chloride sodium-magnesium mineral water with Naftussya water causes significant changes in the constellation of EEG parameters, which are different from the effects of Naftussya water monotherapy.

Using the algebraic approach described in the previous article [2], we modeled the neurotropic effects of mineral waters **themselves**.

Three patterns of neurotropic effects of mineral waters emerge (Fig. 3). The first pattern (12 parameters) reflects a more or less pronounced activation of neurons that generate delta, alpha and beta rhythms, as well as a right-hand shift of symmetry of beta-rhythm. In contrast, the antipode pattern (17 parameters) reflects the inhibition of neurons that generate delta,



alpha, and theta rhythms and the left-hand shift of theta-rhythm symmetry, as well as the decrease in EEG entropy. The intermediate position in the profiles is occupied by 5 parameters, the changes of which are insignificant.



**Fig. 3. Profiles of real Z-scores of initial discriminant EEGs variables and their simulated Z-scores after consumption of sulphate-chloride sodium-magnesium mineral waters**

Since the described neuromodulation is accompanied by physiologically favorable changes in HRV, immune and metabolic parameters [2], a priori it is also favorable. In the next article, this assumption will be verified by correlation analysis.

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### ACCORDANCE TO ETHICS STANDARDS

Tests in patients are carried out in accordance with positions of Helsinki Declaration 1975, revised and complemented in 2002, and directive of National Committee on ethics of scientific researches. During realization of tests from all participants the informed consent is got and used all measures for providing of anonymity of participants.

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