RECREATIONAL DEVELOPMENT OF THE NATURAL ARJAAN'S COMPLEX "CHOIGAN'S MINERAL WATERS" OF THE REPUBLIC OF TUVA

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Abstract: Natural arjaan's complex "Choigan's mineral waters" (arjaan Choigan) is a unique deposit of thermal and cold mineral carbonic waters, located in the extreme North-East of the Republic of Tuva in the Eastern Sayan ranges. This paper presents an overview of the data on hydrogeochemical, medical and biological researches obtained by the authors in 2011 - 2013.

Keywords: comprehensive researches, mineral waters, Tuva.

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Introduction:

The Republic of Tuva has a unique geographical location – on the border of South-Siberian forests and Central-Asian steppes and deserts. There are various types of hydromineral resources due to the peculiarities of its local relief, climate, geological structure and hydrogeological conditions. Tuva has practically all of the well-known types of mineral waters which are diffused along the Russian Federation and former USSA territories: nitric and carbonic thermal; carbonic cold waters; radon waters; salt waters; hydrosulphuric waters; acid waters; arsenious waters and so on.

One can subdivide the hydromineral resources of Tuva with certain conditionality on six isolated hydromineral areas (Fig. 1):

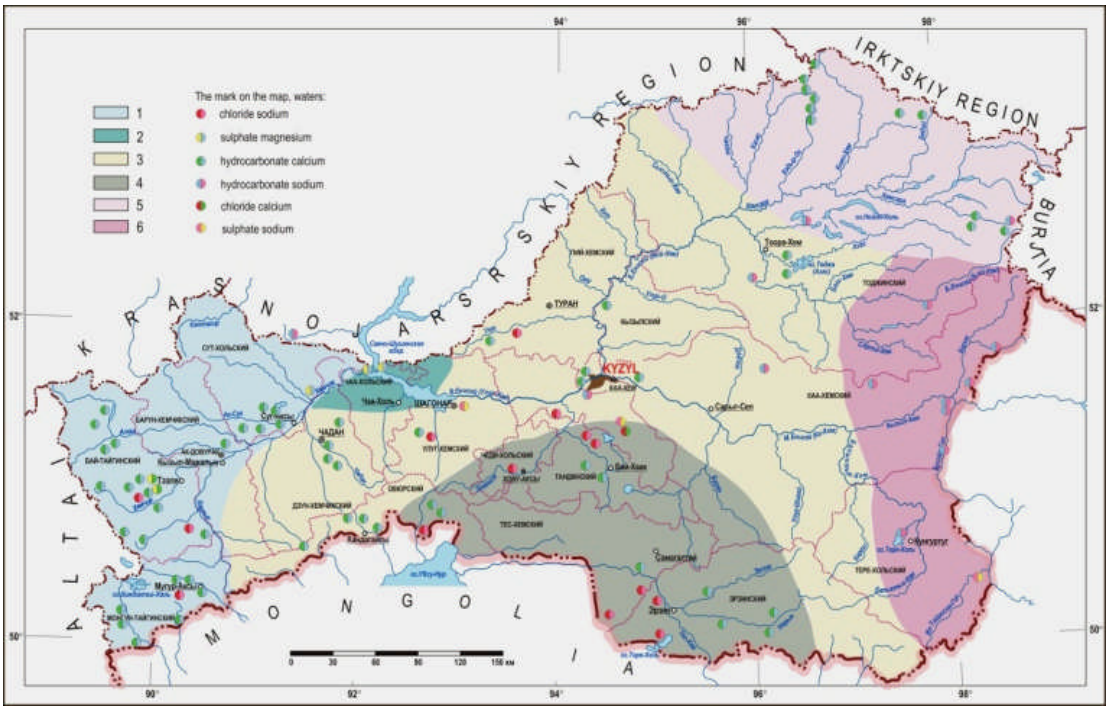
- Altai-West-Sajan area of radon's waters (1);
- West Sajan area of acid waters (2);
- Central Tuvan area of ground and surface waters with various compositions-radon, hydrosulphuric, salt and brine (3);
- Uvs-Nuur area ground and surface salt waters (4);

- East-Siberian area of carbonic and nitric thermal (5);
- Near Khubsugul area of nitric thermal (6).

Several tens of thousand people are resting and improving their health by the folk methods of spontaneous arjaan's treatment every year. This phenomenon of "arjaan's treatment" – is the most ancient national tradition of the Central Asian region ethnic groups. And the arjaan's treatment is an integral part of ethno medical practice of the Tuvan people that absorbs the elements of prevention, rehabilitation and, in general, restorative medicine as such.

One of the most well-known mineral medicinal waters of Tuva is the arjaan Choigan. It is the largest deposit of thermal and cold carbonic waters in the East Sayan. In 2011 - 2013 we conducted a comprehensive scientific research of sources and territory of this arjaan again, and medical-biological studies of spontaneous balneotherapy by using folk methods of arjaan's treatment at the first time. We position arjaan Choigan as the natural arjaan's complex "Choigan's mineral waters".

Figure no. 1 Hydromineral resources areas of Tuva.



Materials and methods:

Comprehensive studies have been conducted by using the known methods of natural sciences - of hidrogeochemistry, geophysics, and the methods of radon - and helium metric studies, methods of GIS-technologies for mapping the territory of arjaan on various hydrogeochemical parameters. These methods are presented in our works (Arakchaa et al. 2011, 2012, 2013; Ayunova et al. 2014).

Medical and biological researches of spontaneous folk treatment on arjaan Choigan we conducted by using the methods of prenosological diagnostics for the

evaluation of the patients' health level. These methods are presented in our works (Smirnova et al. 2013).

Results and discussion:

Carbon dioxide thermal waters found in nature are very rare. Natural arjaan's complex "Choigan mineral waters" (arjaan Choigan) is situated on extreme North-East of Republic of Tuva up the East Sayan Mountain range. Absolute altitudes are 1550–1580 m. The Eastern Sayan range is the region of modern and recently extinct volcanoes. Also, young volcanism is manifested on separate sites along faults here. And Choigan's sources are associated with large latitudinal fault in Precambrian rocks (gneiss, marbles, slates), broken by Paleozoic granite and diorite, and, correspondingly, have a deep origin. A sign of that serve high temperature and the presence of significant quantities of carbon dioxide. It should be noted that the high content of carbon dioxide is observed in the so-called gas funnels with outputs of dry jets of carbon dioxide (Pinneker 1968). The deep circulation of the thermal springs of Choigan is estimated at 1500 – 2000 m (Danilova et al. 2009).

Natural scientific researches and GIS-technology map applications

During the field research of 2011 - 2013, we registered 33 sources used for medicinal purposes, including funnel with dry carbon dioxide, on the territory of arjaan Choigan. The exits of the underground waters are located on the right bank of river Arjaan-Khem, mainly, on the surface of the first river terraces along the basic slope and in the floodplain of the right and left banks of the river (Fig. 2, Annexes). The sediment of modern travertine fields accompanies unloading of hot and cold carbon sources, and this travertine fields have brown color due to the presence of iron oxide and hydroxide minerals. The temperature regime (T ^{o}C) and the Red-Ox potential (Eh, mV) of arjaan's sources are presented in Figure 3 (Annexes).

Choigan mineral waters on anionic macrochemical composition belong exclusively to hydrocarbonate, on cationic - mainly to sodium-calcium and to a lesser extent - to calcium-sodium. Mineralization of the absolute majority of springs is 1.1 - 2.7 g/dm3, less than this amount - in the waters of the springs (Fig. 2, nos. 4, 29 and 33, Annexes).

The composition and geochemical conditions of forming Choigan sources depend on the hydrodynamic conditions of supply and discharge of these waters. They can be divided into three main groups (Arakchaa et al. 2013) (Fig. 4, Annexes):

- waters of faults zones reduction geochemical conditions (a);
- waters of zones regional fissure oxidative geochemical conditions, enriched with carbon dioxide (b);
- ground waters' oxidation in geochemical conditions (c).

The picture in Figure 4 shows that the waters group (a) is characterized by more high temperature (maximum 37 - 39 ^{o}C in water springs (numbers 13 and 12) and, consequently, more high mineralization (M) than others. However, the carbon dioxide content in this water group is lower than in the group of waters (b). The groundwaters group (c) has the lowest mineralization (less than 1 g/dm^3) and practically does not contain carbon dioxide and radon.

Radon content, as seen from Figure 4, does not correlate with other parameters. The maximum of its content is observed in the springs numbers 9, 2 and 3, reaching, respectively, 948, 570 and 520 Bq/dm^3. Balneological standards of radon (200 Bq/dm^3) (Bogolyubov 2008) and much more are also contained in the springs numbers 7 (202 Bq/dm^3), 8 (360), 11 (230), 27 (400) and 28 (355).

Below we give the average Kurlov formulas for these (a), (b), (c) groups of sources (1 - 3) and for individual mineral springs (1a, 2b):

(a) - group, average (1)

CO_2 720 M 2.3

$$\frac{HCO_3\ 96.7\ Cl_2\ SO_4\ 1}{Ca\ 46\ Na\ 39.7\ Mg\ 7.6\ K\ 3.9}$$

pH 6.5 T 21.8 ^{o}

(a) - group, N 12 (1a)

CO_2 691 M 2.5

$$\frac{HCO_3\ 97\ Cl_2\ SO_4\ 1}{Ca\ 43\ Na\ 45\ Mg\ 8\ K\ 4}$$

pH 6.6 T 39 ^{o}

(b) - group, average (2)

CO_2 840 M 1.3

$$\frac{HCO_3\ 94.1\ SO_4\ 4.5\ Cl1}{Ca\ 59.7\ Na\ 29.8\ Mg\ 7.9\ K\ 2.6}$$

pH 6.3 T 17.4 ^{o}

(b) - group, N 4 (2b)

CO_2 1488 M 0.7

$$\frac{HCO_3\ 97\ SO_4\ 2\ Cl1}{Ca\ 70\ Na\ 19\ Mg\ 8\ K\ 3}$$

pH 5.8 T 12 ^{o}

(c) - group, average (3)

CO_2 0.02 M 0.65

$$\frac{HCO_3\ 92\ SO_4\ 4.5\ Cl\ 4.5}{Ca\ 92\ Na\ 1\ Mg\ 6.5\ K\ 0.5}$$

pH 7.5 T 9 ^{o}

where mineralization M - g/dm^3, CO_2 - mg/dm^3, ions - the percentage-equivalent (%).

The range of physical-chemical characteristics for sources of groups (a) and (b) are presented in Table 1 (Annexes), micro-biological characteristics in Table 2 (Annexes). Table 3 (Annexes) presents microcomponents of individual sources of arjaan Choigan.

Based on the presented Figures 2, 3, 4 and 5 (Annexes) and Tables 1, 2 and 3 (Annexes) we can draw the following conclusions:

- the Choigan arjaan springs are thermal and cold mineral carbonic waters unloaded on a relatively small area
- these waters are divided into three groups.

Microbiological characteristics of the surveyed sources need additional research. Considering the microcomponent composition, it should be noted that the content of such elements as Li, Be, Al, Ga, Se, Rb, Nb, Cs, Ba, La, Ce, Eu, Lu and Th is higher than their average concentration (Clarke) in the hydrosphere (Solovov et al. 1990).

There is presented the geomagnetic field view of the Choigan territory in Figure 5 (Annexes) (Arakchaa et al. 2013). Thus, the Choigan springs have a unique composition of biologically active components – carbon dioxide, radon, silicic acid, organic carbon. These components are contained in the waters of Choigan in significant balneological quantities (GOST 2001) and, consequently, they positively influence on the human health.

Medical and biological studies

There were held for the first time the medico-biological researches of the spontaneous folk arjaan's treatment on the natural arjaan complex "Choigan's mineral waters" in 2011 – 2013. The aim of the research: the evaluation of the level of somatic health by using prenosological

somato-functional characteristics of patients before and after the traditional folk course of treatment. The largest number of investigated people was in 2012 - 93 patients. Men were 54 (58.1 %), women - 39 (41.9 %), the average age 40.9 years (from 24 to 60 years). The selection of respondents was carried out by random sampling of volunteers. Research methods are presented in our recent work (Smirnova et al. 2013). In the present article we give some indicators, which most clearly reflect the positive impact of treatment on the sources of arjaan Choigan.

Cardiovascular system

At the beginning of the treatment 34 (36.56 %) patients had exceeded of the normative values of systolic blood pressure (SBP) and 31 (33.33 %) - exceeded of the normative values of diastolic blood pressure (DBP). In the process of treatment these patients received a clear hypotensive effect (Tab. 4 and Fig. 6, Annexes). It should be noted, the hypotensive effect of the treatment was more pronounced than in the total sampling for patients with high initial values of SBP and DBP.

Respiratory system

The analysis of the functional state of the respiratory system in the examined patients showed statistically significant changes that characterize the improvement of the functioning of the broncho-pulmonary system (Tab. 5, Annexes).

Adaptive capacity

The analysis of the functional condition of the homeostasis system has allowed an assessment of the adaptive capacity (AP) of the human body. AP – a comprehensive index based on regression relationship between the heart rate, systolic and diastolic blood pressure, age, body weight and growth. As a result of balneotherapy on the Choigan sources AP of the majority of patients has increased, and there is shown decrease in 2.6 times of the frequenlty unsatisfactory adaptation and complete relief of such a state as adaptation failure.

The level of somatic health

The level of somatic health is an integrating result of the carried out clinical and biological researches. The estimation of this indicator allows a comprehensive evaluation of the patient's health.

Studies have shown that at the beginning of treatment the examined contingent was characterized by low levels of health. High and above average level of health was only 6.4 % were younger than 25 years. After treatment, the statistically significant increase of somatic health was identified for majority of the examined patients. It is important to note that the frequency of the low level of health is reduced more than in 2 times in comparison with initial (Fig. 7, Annexes).

Conclusions:

The Choigan arjaan springs are cold and thermal mineral carbonic acid waters unloaded on a relatively small area. They have unique composition of biologically active components – carbon dioxide, radon, silicic acid, iron etc., which have healing properties.

Medical-biological researches have allowed to establish a positive impact of the arjaan’s balneotherapy on the health of the examined patients.

There can be arranged resorts and sanatoriums on the Choigan carbon dioxide sources as the therapeutic natural resources of Tuva.

Rezumat:

DEZVOLTAREA AGREMENTULUI ÎN COMPLEXUL NATURAL ARJAAN "APELE MINERALE CHOIGAN" DIN REPUBLICA TUVA

Complexul Natural Arjaan - "Apele minerale Choigan" (arjaan Choigan) - este un depozit unic de ape termale şi ape minerale carbogazoase reci, situat la extremitatea de nord-est a Republicii Tuva, la est de regiunea Sayan. Această lucrare prezintă un punct de vedere general al datelor rezultate din cercetările hidro-geo-chimice, medicale şi biologice obținute de autori în perioada 2011 - 2013.

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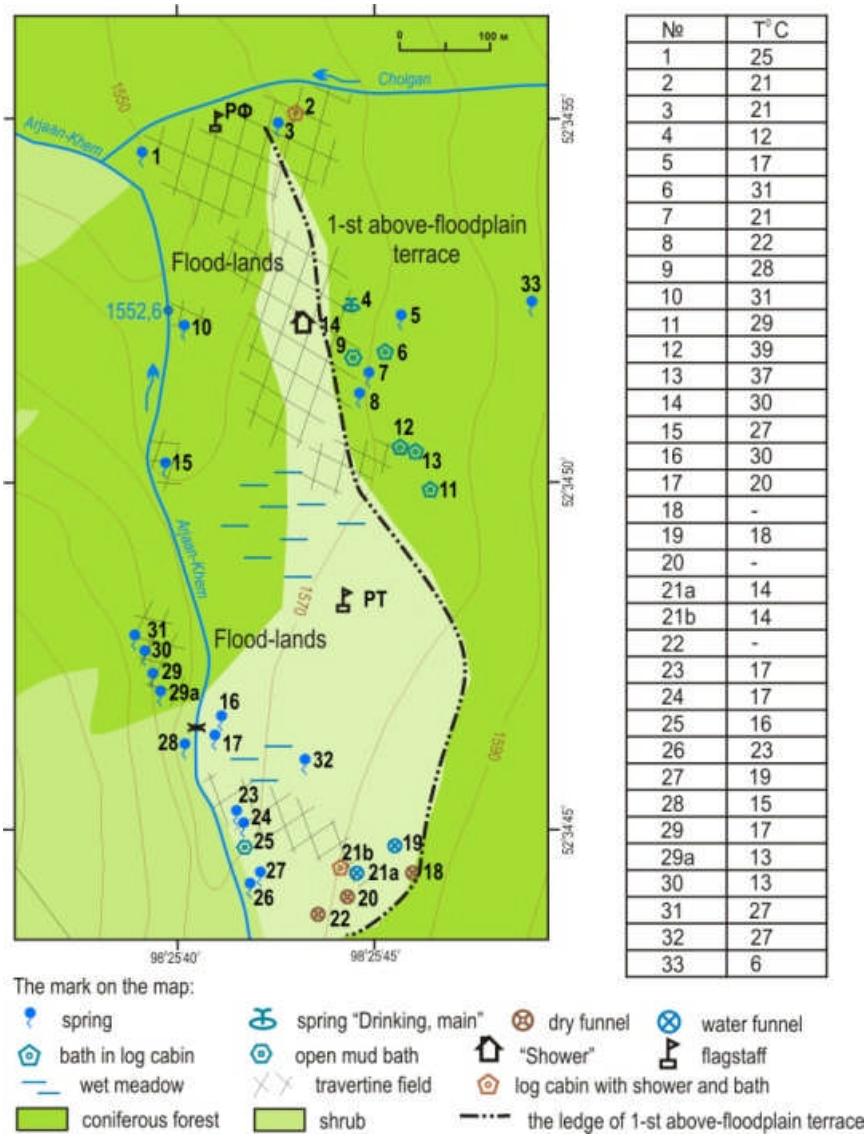
Annexes:

Figure no. 2 Map of the arjaan Choigan's mineral springs.



№	T°C
1	25
2	21
3	21
4	12
5	17
6	31
7	21
8	22
9	28
10	31
11	29
12	39
13	37
14	30
15	27
16	30
17	20
18	-
19	18
20	-
21a	14
21b	14
22	-
23	17
24	17
25	16
26	23
27	19
28	15
29	17
29a	13
30	13
31	27
32	27
33	6

Figure no. 3 Map of distribution T °C and Eh (mV).

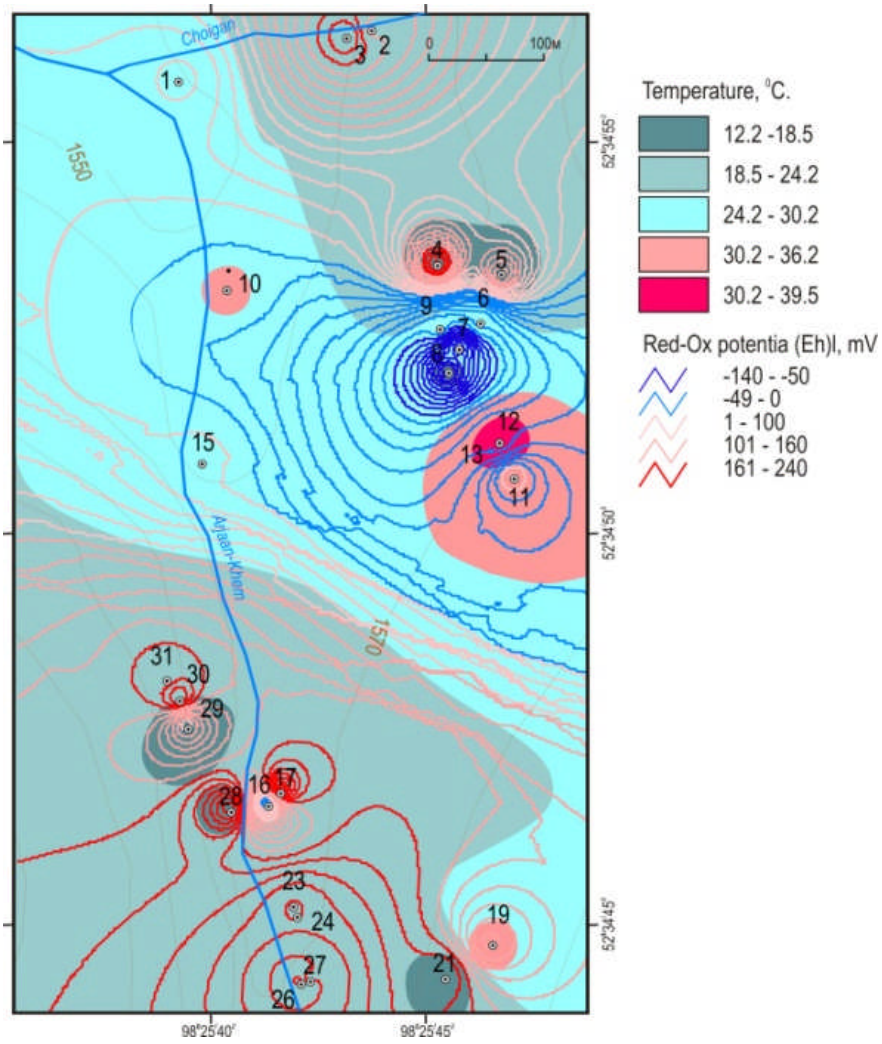


Figure no. 4 Characteristics of separate parameters of Choigan springs in depending on Red-Ox potential (Eh).

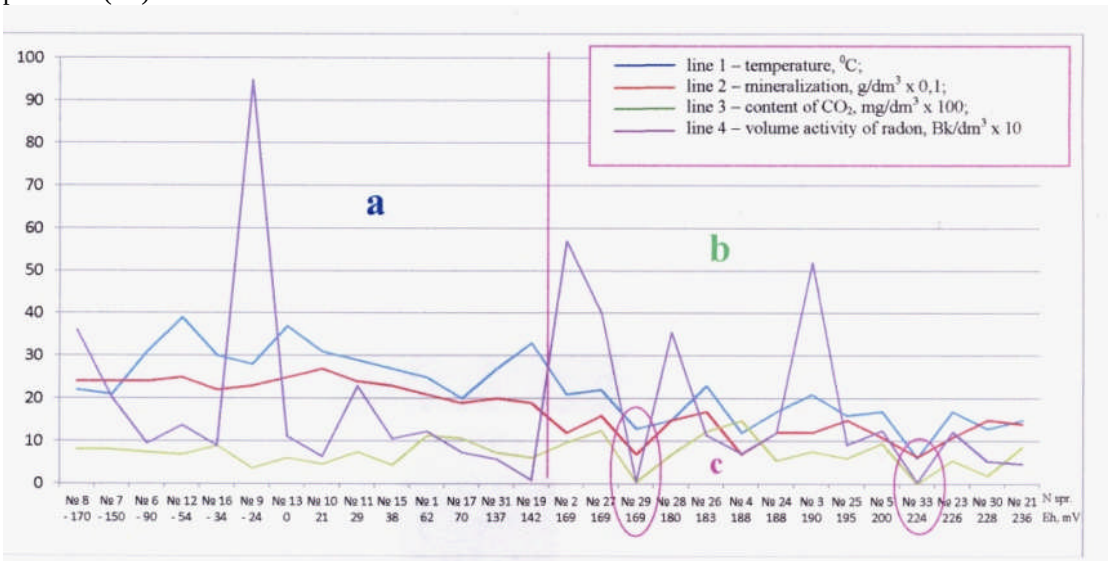


Figure 4. Characteristics of separate parameters of Choigan springs in depending on Red-Ox potential (Eh):
a) waters of faults zones reduction geochemical conditions;
b) waters of zones regional fissure oxidative geochemical conditions, enriched with carbon dioxide;
c) ground waters oxidation geochemical conditions (springs NN 29, 33).

Figure no. 5 View of Choigan arjaan's territory geomagnetic field.

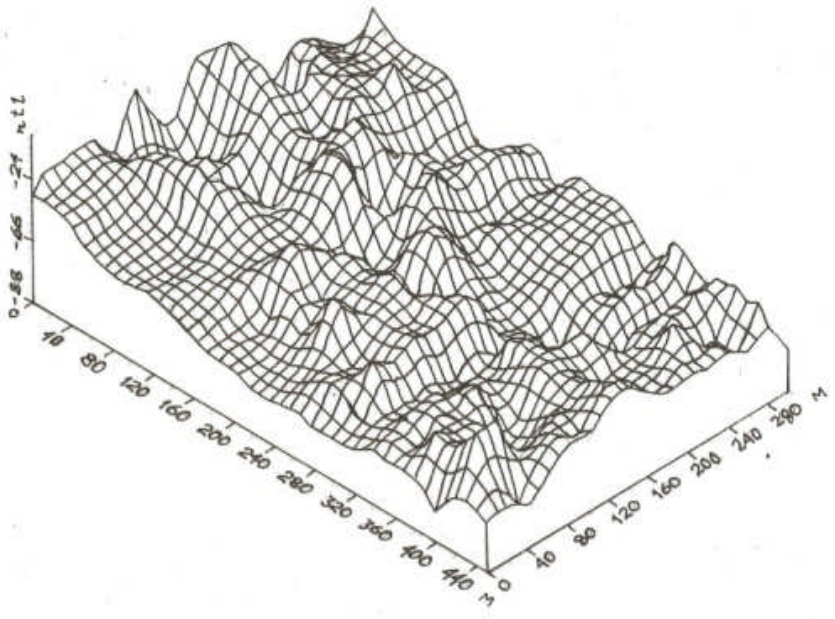


Figure no. 6 The frequency of registration of high values SBP, DBP and Heart rate upon studied patients.

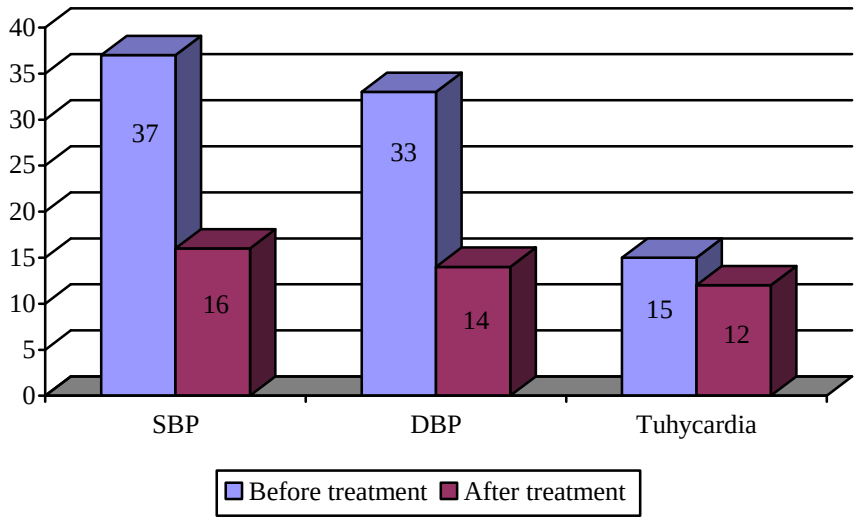


Figure no. 7 The level of somatic health of patients before and after spontaneous balneotherapy of the sources of arjaan Choigan.

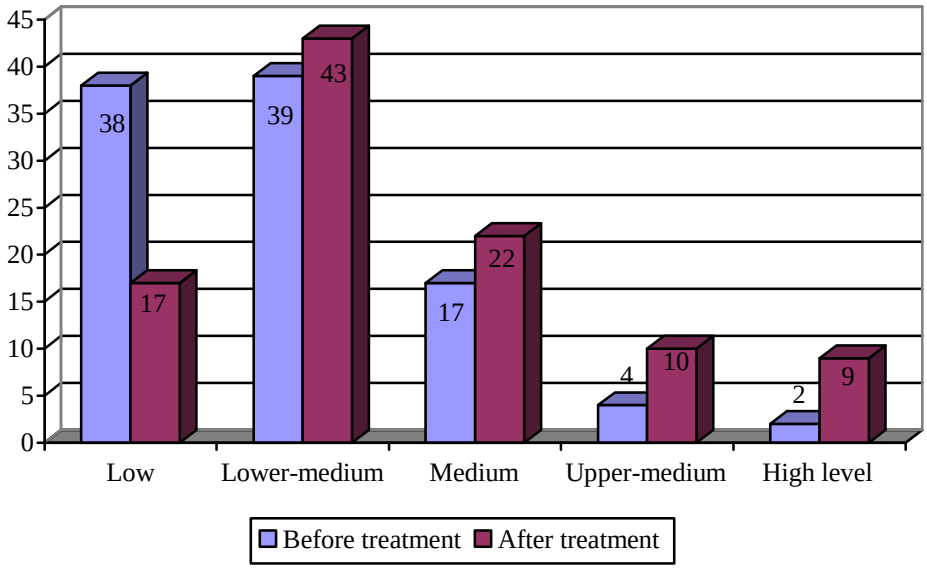


Table no. 1 Physical and hydrogeochemical characteristics of Choigan arjaan springs (Arakchaa et al. 2011, 2012, 2013).

Characteristics	Values
Mineralisation, g/dm^3, including:	0.6 - 3.0
- (a)-group water springs, g/dm^3	1.9 - 2.7
- (b)-group water springs, g/dm^3	0.7- 1.9
Temperature, ^oC	6 - 39
pH (for (a)- and (b)-groups	5.8 - 6.8
CO_2 (dissolved), mg/dm^3	500 - 1500
CO_2 (in gas phase), vol. %	70 - 95
Radon, Bq/dm^3	10 - 950
Silicic acid, H_3SiO_3, mg/dm^3, including:	23 - 72
- (a)-group water springs, g/dm^3	50 - 72
- (b)-group water springs, g/dm^3	23 - 47
Organic carbon, mg/dm^3, including:	to 60
- naphthenic acids, mg/dm^3	0.62 - 0.88
- phenols, mg/dm^3	0 - 0.04
Helium (in dissolved gases) vol. %	(18 - 485) 10^{-7}
Helium (in gas phase), vol. %	(2 - 60) 10^{-4}

Table no. 2 Microbiological characteristics of Choigan arjaan springs (Arakchaa et al. 2012).

No.	Characteristics	Value range
1	Ammonifiers bacteria, cell/ml	44 – 6000
2	Denitrification bacteria, cell/ml	2 – 2000
3	Thiobaccillus denitrificans, cell/ml	1 – > 1000
4	Hungry Munc bacteria*)	200 – 240
5	Propane butane oxidizing bacteria (C_3H_8 + C_4H_{10}), notional units	220 – 260
6	Pentane oxidizing bacteria (C_5H_{12}), notional units	240 – 260
7	Hexane oxidizing bacteria (C_6H_{14}), notional units	200 – 250
8	Heptane oxidizing bacteria (C_7H_{16}), notional units	200 – 250
9	Octane oxidizing bacteria (C_8H_{18}), notional units	210 – 235
10	Nonan oxidizing bacteria (C_9H_{20}), notional units	210 – 235
11	Dean oxidizing bacteria ($C_{10}H_{22}$), notional units	190 – 250
12	Benzene oxidizing bacteria (C_6H_6), notional units	200 – 250
13	Toluene oxidizing bacteria ($C_6H_5CH_3$), notional units	200 – 250
14	Phenol oxidizing bacteria (C_6H_5OH), notional units	210 – 235

*) Bacteria growing on mineral medium of Muntz, without adding of hydrocarbons (use hydrocarbons sowing water).

Table no. 3 Micro component composition of individual sources of arjaan Choigan (Arakchaa et al. 2011, 2013).

Element	Content of micro components, mg/dm^3		
	N 21a	N 18	N 19
Li	0.134588	0.475327	0.507054
Be	0.000297	0.000574	0.001302
B	0.026	0.092	0.115
Al	0.030	1.294	0.938
Si	7.27	16.02	16.82
Sc	0.001682	0.003989	0.007427
Ti	0.004726	0.002668	0.001665
V	4.86E-05	0.000612	0.001217
Cr	0.004053	0.00769	0.004756
Mn	0.020717	0.252412	0.166018
Fe	1.152556	15.82619	3.421567
Co	0.000282	0.000445	0.001686
Ni	0.002485	0.001966	0.000833
Cu	0.00092	0.006324	0.003185
Zn	0.01478	0.004401	0.013155
Ga	2.29E-06	2.42E-05	6.72E-06
Ge	0.001077	0.002091	0.004334
As	0.001059	0.005851	0.001006
Se	0.001103	0.000776	0.000317
Br	0.00758	0.023868	0.025175
Rb	0.031854	0.108864	0.11048
Sr	1.216477	3.149478	3.289383
Y	0.000196	0.001046	0.000652
Zr	3.22E-05	0.000481	0.000283
Nb	0.000119	0.000262	0.000281
Mo	0.001094	0.000326	0.001305
Ag	2.57E-05	4.73E-05	0.000296
Cd	2.96E-05	4.88E-05	8.17E-05
In	4.41E-07	7.65E-07	7.65E-07
Sn	1.3E-05	0	7.29E-05
Sb	6.12E-05	9.93E-05	5.33E-05
Te	<0.00001	<0.00001	<0.00001
I	0.000168	0.000431	0.000246
Cs	0.006694	0.016845	0.022073
Ba	0.224128	0.845596	0.97034
La	0.000142	0.004508	0.001732
Ce	0.000112	0.010673	0.003894
Pr	3.02E-05	0.000886	0.00039
Nd	0.000103	0.00353	0.001575
Sm	2.3E-05	0.00069	0.000319
Eu	3.03E-05	0.000178	3.44E-05
Gd	3.51E-05	0.000873	0.000341
Tb	4.56E-06	0.00011	5.15E-05
Dy	2.55E-05	0.000483	0.000238
Ho	8.48E-06	9.07E-05	4.42E-05
Er	2.16E-05	0.000246	0.000102
Tm	3.92E-06	3.91E-05	1.48E-05
Yb	2.21E-05	0.000191	0.000115
Lu	4.64E-06	2.98E-05	2.32E-05
Hf	<0.0000006	1.12E-05	4.32E-06

Ta	9.03E-07	5.07E-06	5.5E-06
W	5.55E-06	1.71E-05	5.33E-06
Re	<0.00005	<0.00005	<0.00005
Os	<0.00005	<0.00005	<0.00005
Ir	<0.00005	<0.00005	<0.00005
Pt	<0.000002	<0.000002	<0.000002
Au	<0.000001	3.8E-06	<0.000001
Hg	<0.000004	<0.000004	<0.000004
Tl	2.73E-05	1.03E-05	4.87E-05
Pb	0.000345	0.00222	0.000983
Bi	2.93E-06	7.96E-05	3.06E-05
Th	6.59E-06	0.000167	6.17E-05
U	0.00394	0.001446	0.002697

Table no. 4 Dynamics of the cardiovascular system functional state (Solovov et al. 1990).

Indicators	Before treatment	After treatment	p
SBP, mm Hg	133.93±22.89	126.05±17.10	0.001
Frequency SBP above 140 mm Hg, %	36.56	16.12	0.04
SBP initially increased (more than 140 mm Hg), n=34	157.34±17.66	134.67±14.68	0.000
DBP, mm Hg	84.48±16.57	79.95±10.34	0.002
Frequency DBP above 90 mm Hg, %	33.33	13.98	
DBP initially increased (more than 90 mm Hg), n=31	101.45±14.04	84.95±9.78	0.000
Heart rate, beats per min	76.47±12.57	76.55±10.58	0.742
Frequency tachycardia, %	15.05	11.83	0.67
HR initially increased (more than 90 beats per minutes), n=13	97.84±7.72	86.00±14.33	0.028
The index of the heart (double multiplication), notional unit	98.71±29.02	90.10±19.97	0.001

Table no. 5 Dynamics of the respiratoru system functional state.

Indicators	Before treatment	After treatment	p
Shtange test, sec.	30.69±9.83	35.47±14.93	0.001
Genchi test, sec.	17.99±6.10	20.40±7.62	0.001
SpO_2, %	99.67±1.93	97.50±0.93	0.001

Note: SpO_2-the indicator of the oxygen saturation of the blood, obtained by using of pulseoximeter.