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Geothermal Resources of Tajikistan

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ABSTRACT

Through the efforts of scientists from different countries in the last century, extensive geological, hydrological, geophysical and geochemical studies were carried out in Tajikistan. As a result of numerous scientific expeditions, maps of geothermal fields were compiled, that form the basis of scientific research in this area today. Out of the 28 largest thermal springs, 8 are located in Central Tajikistan, and 20 in the high-mountainous Pamirs. The total resource of the geothermal sources identified to date is 151 million kWh per year, which corresponds to a capacity of 17.2 MW. Based on some of these sources (Khoja Obi Garm (98^{o}C), Dzhilandy (67.5^{o}C), Garm Chashma (60^{o}C), Khovatag (55^{o}C), Obi Garm (53^{o}C), Yamchun (43^{o}C), Yavroz (42^{o}C), Avdzh (34^{o}C)) centers of health, recreation, balneology and tourism are organized. The rest of the sources are used to heat the homes of local residents and greenhouses. It should be noted that deep geothermal springs (more than 200 m deep) have much higher energy and can be used as sources of electricity. Unfortunately, at the moment, the country lacks a developed base of deep well drilling technologies.

1. INTRODUCTION

Tajikistan is located in the South-East of Central Asia; the total area is 141.400 km2. Tajikistan has a border with China on the east, Uzbekistan on the west, Kyrgyzstan on the north and Afghanistan on the south (Fig. 1). It lies between latitudes 36° and 42°n, and longitudes 67° and 75°e. The capital of Tajikistan is Dushanbe.

By the nature of the surface, Tajikistan is a typically mountainous country with absolute heights from 300 to 7495 meters, 93 percent of its territory is occupied by mountains belonging to the highest mountain systems of Central Asia, Pamir and Tian-Shan. Tajikistan's total population is 9,7 million (September, 2020) and the population growth rate stands at 3,5 percent (Would Population Review, 2020).

In Tajikistan the main catchments are glaciers. The largest glacial system is the Pamir, the area of glaciation of which within the CIS is 8041 sq. km. The number of registered glaciers in the Pamir is 1,085.

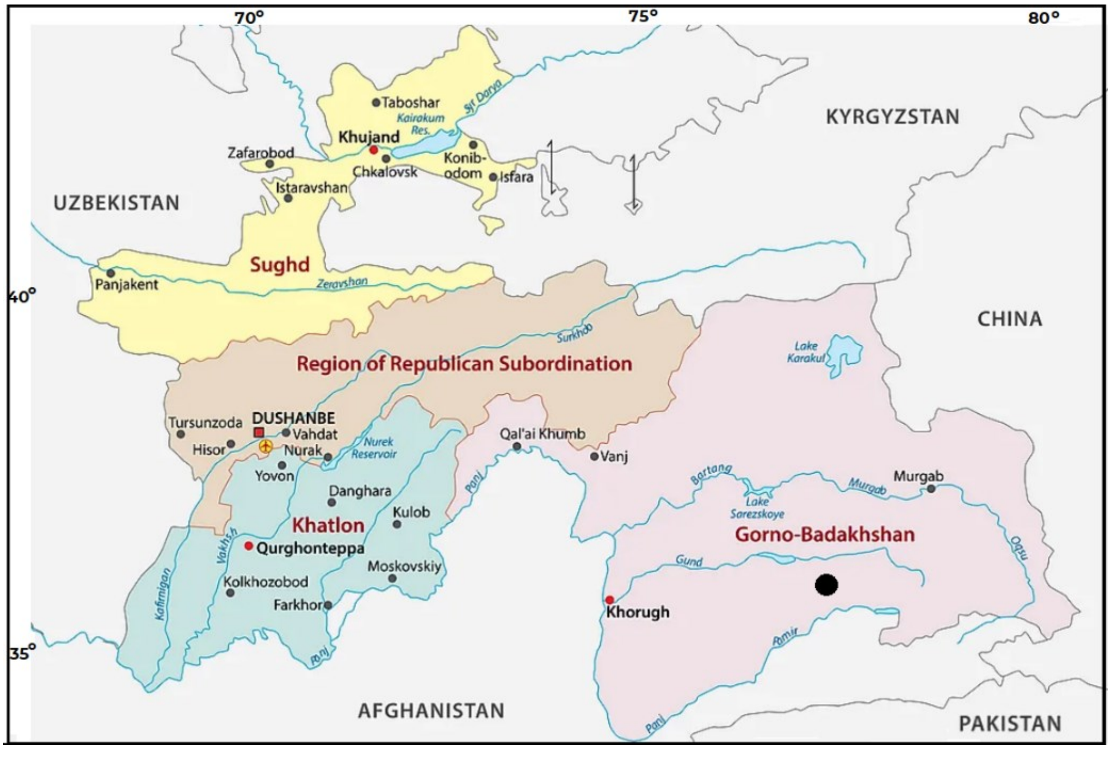

Figure 1: Map of Tajikistan

1.2 State and Political System

Tajikistan is a presidential-parliamentary state. The President of Tajikistan is elected by direct popular vote for a term of 7 years, and the Parliament of the country for a term of 5 years. The President is also the Chairman of the Government. Parliament consists of two chambers: Upper (Majlisi Milli) and Lower (Majlisi Namoyandagon). Parliamentary elections are held on the basis of a mixed system (majoritarian and party lists). The last presidential and parliamentary elections were held in 2020. The administrative-territorial division of the country includes the Gorno-Badakhshan Autonomous Region, Sughd and Khatlon regions, Regions of Republican Subordination, and the city of Dushanbe.

In recent decades, the country has seen economic growth and an increase in the well-being of the people. GDP is growing at a good pace. New hydroelectric power plants were put into operation: Sangtudinskaya HPP and Sangtudinskaya-2 HPP. Construction of the largest in Central Asia Rogun HPP with a design capacity of 3,600 MW is well under way.

The government of the country is taking measures to strengthen the transport networks of the country, break the communication deadlock, and achieve energy independence and food security of the country.

1.3 Lead Agencies Involved in Geothermal Energy

Some of the agencies that may be eligible to become lead agencies in geothermal activities are:

i. Center of Innovative Development of Science and New Technologies (CIDS&NT), National Academy of Sciences of Tajikistan;

ii. Department of Renewable Energy Sources, Tajik Technical State University;

iii. Ministry of Energy and Water Resources of the Republic of Tajikistan.

The first two agencies can serve as Research and Development Institutions while the third can take legislative initiative in developing legal documents and installation wells and pumps for research and demonstration purposes.

2. GEOLOGICAL AND HYDROGEOLOGICAL INFORMATION

Over the decades, significant geological research has been carried out on the neogeotectonics of Tajikistan. First of all, it is necessary to introduce an article by German geologists (Bernd Schurr and etc., 2014). The main conclusion of the authors is that the structure of the shear deformation of the western Pamirs and the tectonic activity of the Sarez-Karakul fault system may cause further spread of the northwestern margin of India to the northeast into Eurasia, thereby linking the deformation in the Pamirs to the Chaman Fault in the south of Afghanistan. In the article new seismic data are presented which shows that the shortening due to the Pamir northern depression is concentrated along the thrust system along its northern perimeter. The Pamir thrust is adapted to the general convergence of India and Eurasia at this longitude. A large set of local seismic data was used together with the mechanism of origin and deployment in a two-year period, the characteristics of the GPS measurements taken during this period were given, and an assessment of the Cenozoic structures was given together with the current deformation field of the Pamirs (Fig.2). Unfortunately, at present there is no such in-depth analysis of geothermal manifestations in the study area, which can also serve as a research base for geothermal tectonics. For completeness, we present here an overview tectonic map of Southeast Central Asia, developed by the authors.

The Pamir marginal foothill trough arose in the era of alpine mountain building and contains various basins of thermal waters. In particular, the thermal waters of the South Pamir hydrogeological massif demonstrate a unique variety of chemical types from fresh (drinking) to brine, used as mineral raw materials for the extraction of valuable elements. The indicated hydrogeological massif consists of the Murghab - Bartang, Alichur and Shahdara hydrogeological zones. In the Murghab-Bartang and Alichur zones, the outflows of thermal waters are associated with the occurrence of siliceous terms, in the Shahdara zone with hot carbon dioxide springs and siliceous terms (Ilolov M. etc., 2015). According to V.N. Krat's classification (Krat V.N., 1985) thermal springs include mineral waters with a temperature of 20 ºC and above. Depending on the temperature, thermal waters are divided into low-thermal (20-50 ºC), thermal (50-75 ºC), high-thermal (75-100 ºC) and superheated (100 ºC and above).

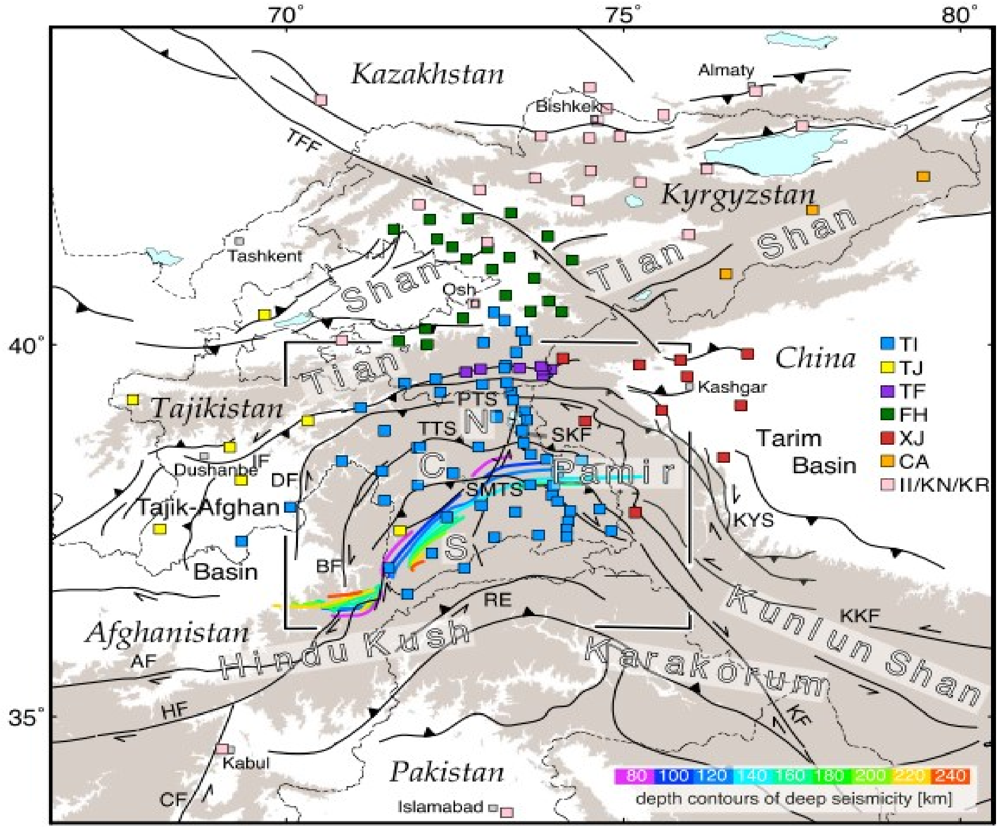

Figure 2: Tectonic Overview Map of Western Central Asia with Main Neotectonic Structures Drawn as Black Lines.

Abbreviations are AF = Andarob Fault, BF = Badakhshan Fault, CF = Chaman Fault, DF = Darvaz Fault,

HF = Herat Fault, KKF = Karakax Fault, KF = Karakorum Fault, KYS=Kashgar-Yecheng Transfer System,

IF = Illiac Fault, RE = Reshun-Hunza Fault System, PTS = Pamir Thrust System, SKF = Sarez-Karakul Fault System, SMTS = Sarez-Murghab Thrust System, TFF = Talas Ferghana Fault, and TTS =Tanymas Thrust System.

3. RESOURCES OF RENEWABLE ENERGY SOURCES AND THEIR POTENTIAL USE

Recently, it has become obvious that the further development of renewable energy sources should not be associated with the problems of global warming of the Earth. Systematic scientific research on the causes of climate change is required, but this does not mean abandoning the focus of future energy on renewable energy sources. RES are new areas of research, new breakthrough technologies, new sources of energy storage and, therefore, the future economic growth of the countries of the world. Among the promising directions for the development of renewable energy sources, one should name geothermal energy in the form of hydrogeothermal and petrothermal energy. Usually, geothermal energy means hydrothermal, i.e. energy of hot underground water sources. If the water is very hot (more than 160° C), then a conventional steam cycle can be used to generate electricity. For less hot water up to 70^0C, binary cycles with two circuits must be used. In the first circuit, geothermal water circulates, and in the second circuit, the vapors of a lightly boiling substance such as freon drive the freon turbine. Binary cycle stations are widespread in the world, and about half of such stations are used to solve problems of electricity saving, i.e. electricity is generated not only from hot geothermal water, but also from waste heat from enterprises and housing and public utilities. Particularly such technologies must be developed in our small countries. It is necessary to develop binary installations operating at low potential heat. Large, developed countries can afford to develop the second component of geothermics - petrothermal energy. It is based on the deep heat of dry fallows at a depth of 3 to 10 km. By the way, the first geothermal circulation system (GCC) was proposed by the Russian academician Obruchev back in the 30s of the last century. The principle of operation of the GCC is very simple: 2 wells are drilled, water is supplied one by one, and steam and hot water rise along the other, but for the pumped water to go and heat up, the vapor must be permeable, usually this is not the case, since at such depths there are predominantly dense basaltic beds. The next step is to involve new methods such as the Enhanced Geothermal System (EGS). The EGS concept is based on early Hot Dry Rock (HDR) research by Los Alamos National Laboratory in the USA.

3.1 Renewable Energy Sources in Tajikistan and their Potential Use Background

There are two main reasons for the upsurge of interest in renewable energy sources at the end of the last and the beginning of this century. The first one relates to the limited mineral resources, on which the entire world energy industry is based.

It is customary to conditionally divide RES into two groups (Petrov V.N. etc., 2009).

Traditional: hydraulic energy converted into a usable form of energy from hydroelectric power plants with a capacity of more than 30 MW; biomass energy used to generate heat by traditional combustion methods (firewood, peat and some other types of heating oil); geothermal energy.

Nontraditional: solar and wind energy, energy of sea waves, currents, tides and the ocean, hydraulic energy converted into a usable form of energy by small and micro hydroelectric power plants, biomass energy not used to generate heat by traditional methods, low-grade thermal energy and other "new" types of renewable energy.

It can be noted that this classification is rather arbitrary and does not play a large practical role, with the exception of one point. In accordance with it, hydropower is divided into two different categories and HPPs with a capacity of less than 30 MW are classified as RES. According to what was done in (Petrov V.N. etc., 2009) of this review and analysis, the resources of renewable energy sources in Tajikistan are estimated by the following values, given in Table. 1.

Table1: Resources of renewable energy sources in Tajikistan, mln tons of fuel equivalent in year

Resources	Gross potential	Technical potential	Economic potential
Hydropower, total	179.2	107.4	107.4
incl. Small	62.7	20.3	20.3
Solar energy	4790.6	3.92	1.49
Biomass energy	4.25	4.25	1.12
Wind energy	163	10.12	5.06
Geothermal energy	0.045	0.045	0.045
Total (excluding large hydroelectric power plants)	5199.795	38.635	28.015

Currently, in Tajikistan, an average of 16.44 billion kW. hours of electricity is generated, which corresponds to 5.6 million tons of fuel equivalent. As the table shows. 1, the technically feasible reserves of renewable energy sources are 6.9 times, and the economically feasible ones are 5.0 times more than the amount of electricity generated annually in Tajikistan (5.6 million tons of fuel equivalent). Thus, this does not mean that it is necessary to completely reorient the entire traditional energy sector of Tajikistan to renewable energy sources. Moreover, as will be shown below, the economic potential of the latter actually has more social significance. A more realistic scenario would be the simultaneous and uniform development of both traditional energy and the development of renewable energy sources.

Technically possible reserves of traditional energy sources in Tajikistan are shown in Table. 2.

Table 2. Technical reserves of energy resources of Tajikistan, mln tons of fuel equivalent a year

Hydropower (without small)	coal	oil	gas	total
87.1	13.35	1.85	0.75	103.05

Given the data in the table. 2, the share of renewable energy sources in the total energy sector of Tajikistan can range from 35% (technical potential) to 27% (economic potential). As you can see from the table. 1, although the share of renewable energy sources in the total energy sector may be significant, its use in Tajikistan, with the exception of small hydroelectric power plants, is practically at zero level (Table 3).

Table 3. Inventory data on the share of various sources in the structure of energy consumption of the Republic of Tajikistan

Types of energy sources	Share in % 1990 г.	2007 г.	2017 г.*
Electricity (HPP)	48.6	75.3	80.1
Petroleum products	28.8	11.10	9.7
Gas (natural)	17.7	12	8.7
Coal	4.8	1.45	1.1
Renewable energy sources (micro HPP)	-	0.174	0.4

*Source: Statistical Yearbook of the Republic of Tajikistan, Dushanbe (2018)

Experience shows that in many countries the use of RES has become an important factor in their sustainable development (https://chrdk.ru/sci/intervyu-alekseenko). The governments of these countries are actively promoting the use of renewable energy sources, while on a global scale there are number of programs for the development of technologies in this area. For countries that have small reserves of fossil fuels or have a polluted environment, RES are the best alternative. In 2007, Tajikistan adopted a Target Comprehensive Program for the Use of RES in the Republic, the purpose of which is the creation, development and widespread use of promising technologies for the production of electrical and thermal energy based on renewable energy resources, making a contribution to the fuel and energy balance of the country, assistance in raising the living standards of the population through the introduction of modern technologies for the use of renewable energy sources, training highly qualified personnel in the field of renewable energy. This paper analyzes the resources of renewable sources in Tajikistan and indicates the possibilities of their use.

3.2 Geothermal Energy in Tajikistan

Tajikistan is rich in thermal sources. A particularly large number of them are in the Pamirs. The experience of other countries shows that thermal waters are of interest for generating electricity if their temperature is not lower than 150 and even 300 ° C. Thermal water sources with temperatures over 60 ° C , are of interest for heating. The total yield of eight sources in Tajikistan is 20.25 l/s. The rest of the sources can be used only for hot, or rather, warm water supply. Basically, any energy can be converted into electrical or thermal energy. In this case, geothermal heat energy is of particular interest, since in terms of electricity it is not essential. At the same time, as a source of thermal energy, it can be of great interest, especially when using modern technologies in the form of heat pumps. In this case, it is possible to use all the low-grade heat of geothermal source, corresponding to a water temperature above 15 ° C. In this case, the total resource of heat energy from the geothermal source can be calculated by the formula:

$$Q = V \times (\Delta t),$$

where Q is heat resource of the geothermal source, Kcal / sec, V is yield of the geothermal source, l / sec, Δt is temperature range of the geothermal source that can be used to generate heat, equal to the source temperature minus 15 degrees.

In the 80s of the last century, 10 shallow wells were drilled near natural thermal manifestations, which revealed thermal waters in the Neogene aquifer.

Studies by Soviet geologists and geochemists (Zuev Y.N. etc.) show that in the zone of the South Pamir fault there is an intense release of juvenile gases, among which helium, methane and nitrogen prevail. Of particular note are the high concentrations of helium found in many thermal springs. This fact allows us to consider the Pamirs as a new helium geochemical province. Helium is used in spacecraft to create excess pressure in fuel tanks, it is used in the nuclear industry, cryogenic processing, the study of superconductivity, fiber-optic cables, and liquid crystal screens. Helium enters the composition of respiratory mixtures, it is used in magnetic resonance imaging. Recently, helium has begun to be used in microelectronics to increase the recording density on hard drives. A deep exploration program needs to be implemented to prove the existence of deep productive horizons in the metamorphic basement.

A deep exploration program needs to be implemented to prove the existence of deep productive horizons in the metamorphic basement. Deep exploration wells will allow us to check the existence of permeable horizons in the metamorphic basement (2500-3500 m) with high productivity, temperatures (200-300 ° C) and pressures of 4-7 MPa. It is possible that the fields of Dzhilandy, Tokuzbulak and Javshangoz, which are now considered as separate geothermal objects at the level of not deeply deposited carbonic and siliceous springs, actually belong to the same geothermal system.

At the same time, the method of reflected seismic waves plays an important role in determining a deep geothermal object, i.e., a reliable correlation of seismic markers and permeable zones of disturbances in the metamorphic basement. This, in turn, presupposes an accurate knowledge of the currents in geothermal reservoirs.

Table 4 shows the calculations of potential electricity and heat resources for 28 geothermal sources in Tajikistan.

Table 4 Geothermal springs in Tajikistan

№	Source, well	Temperature C°	Flow rate l/s	Heat and electricity resources			
				Kcal / sec			kWh / sec	million kWh / year
Central Tajikistan							
1	Khoja-Obigarm	98	1.50	124.50	3926.23	0.145	4.57
2	Tamdykul	88	0.65	47.45	1496.38	0.055	1.74
3	Khovatag	55	11.70	468.00	14758.85	0.544	17.16
4	Obi-Garm	53	14.80	562.40	17735.85	0.654	20.62
5	Obisafet	51	12.00	432.00	13623.55	0.502	15.84
6	Garmova	42	1.30	35.10	1106.91	0.041	1.29
7	Yavroz	41.5	9.00	238.50	7521.34	0.277	8.75
8	Yamankyrchin	33	3.00	54.00	1702.94	0.063	1.98
Pamir							
9	Kauk	76	4.00	244.00	7694.78	0.284	8.95
10	Issykbulak	71	1.50	84.00	2649.02	0.098	3.08
11	Jilandy	67.5	5.60	294.00	9271.58	0.342	10.78
12	Tokuzbulak	66	2.00	102.00	3216.67	0.119	3.74
13	Elisu	63.5	1.50	72.75	2294.24	0.085	2.67
14	Jartygumbez	62.5	3.50	166.25	5242.86	0.193	6.10
15	Garmchashma	60	1.50	67.50	2128.68	0.078	2.48
16	Langar	49	1.50	51.00	1608.34	0.059	1.87
17	Yamchin	43	3.00	84.00	2649.02	0.098	3.08
18	Kokbai	40	4.00	100.00	3153.60	0.116	3.67
19	Bakhmyr	38	0.40	9.20	290.13	0.011	0.34
20	Kyzylrabat	38	1.60	36.80	1160.52	0.043	1.35
21	Jaushangoz	36	10.00	210.00	6622.56	0.244	7.70
22	Shirgin	35	6.00	120.00	3784.32	0.140	4.40
23	Shakhdara	35	12.00	240.00	7568.64	0.279	8.80
24	Avj	34	4.20	79.80	2516.57	0.093	2.93
25	Koytezak	33	1.50	27.00	851.47	0.031	0.99
26	Sasykbulak	32	2.00	34.00	1072.22	0.040	1.25
27	Khanyuli	32	5.70	96.90	3055.84	0.113	3.55
28	Darshai	31	2.30	36.80	1160.52	0.043	1.35
Total				4118.0	129863.7	4.8	151.0

Thus, the total resource of geothermal sources in Tajikistan is 151 million kWh per year, which corresponds to a capacity of 17.2 MW.

It can be assumed that the technical and economic potential of geothermal sources is equal to the potential.

Hence, we find that the resources of geothermal sources in Tajikistan can be estimated by the following values:

- Gross potential - 17.2 MW = 0.045 million tons of fuel equivalent / year

- Technical potential - 17.2 MW = 0.045 million tons of fuel equivalent / year

- Economically viable potential - 17.2 MW = 0.045 million tons of fuel equivalent / year

3.3 Classification of medicinal mineral waters of the Pamirs

According to (Bobokhojaev I.Y., Davlatmamadov Sh. 2010), therapeutic mineral waters are natural waters that contain mineral components and various gases or have specific physical properties: temperature, radioactivity, alkalinity, acidity, and have a therapeutic effect on the human body.

Mineral waters are concentrated in the bowels of the upper layer of the earth, the lithosphere. Groundwater is formed from atmospheric water and it is of magmatic origin. The problem of the origin of mineral waters and their enrichment with various microelements with iron, arsenic, lithium, iodine, and radioactive elements is a complex physicochemical and geological process.

Depending on the temperature and composition of black rocks through which water passes, its mineral and gas composition can be very diverse. The chemical composition and the degree of groundwater mineralization also depend on the depth of the source in the earth's crust. So, in the upper layers of the earth's crust, fresh, weakly - and low-mineralized hydrogen sulfide and ring waters occur; the next lower horizon of the earth's crust contains medium-mineralized (from 5 to 15 g / l) hydrogen sulfide, chloride and sodium waters. In the main part of the earth's crust, there are highly mineralized (from 15 to 35 g / l) chloride, sodium and brine waters, with a degree of mineralization over 35 g / l .

There are various classifications of mineral waters. This is a classification by ionic composition according to (V.V. Ivanov, G.A. Nevraev, 1980).

Modern balneological practice prefers, mainly, the classification of V.V. Ivanov, G.A. Nevraev, taking into account the main features that determine the physiological and healing properties of mineral waters, i.e. ionic and gas composition, total mineralization, physically active ions (trace elements), radioactivity, active reaction of the medium (pH) and the temperature of mineral waters. Depending on these properties, mineral spring waters are divided into:

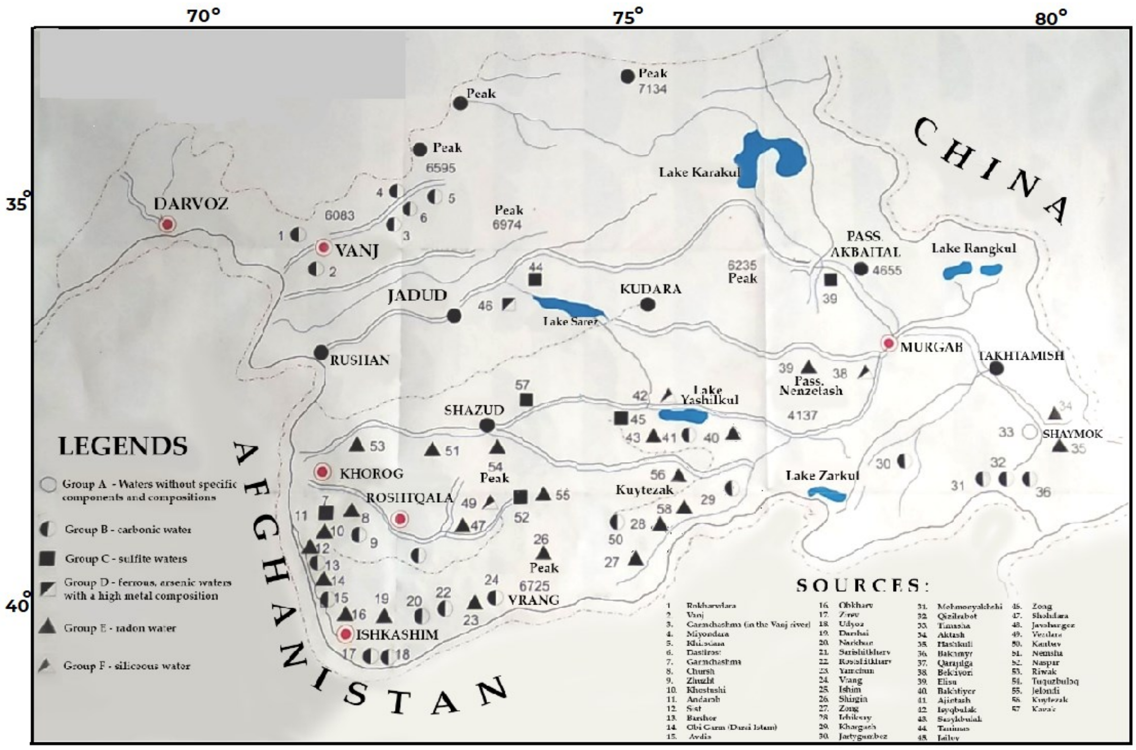

Figure 3: Schematic map of thermal waters of Pamir

Group A. Waters without "specific" components and properties.

The healing properties of these waters are determined only by the basic ionic composition and general mineralization, with insignificant content of nitrogen and methane in their gas composition. This group of waters is found in the Dastirost, Tmeash and Kyzyljigla springs.

Group B. Carbonic waters.

The healing properties of these waters are determined by the presence in them of large amounts of dissolved carbon dioxide, which occupies a dominant position in the total gas composition of these waters, as well as by their ionic composition and general mineralization. Carbonic waters can be recommended for ingestion and in the form of baths, they are most widespread, practically found throughout the entire region. There are 33 such mineral sources in total, including 22 cold, 6 warm and 2 very hot (hyperthermal). The temperature of these sources ranges from the coldest source (Rivak, 5 + 7 ^oC) - in Shugnan, to a very hot one (Dzhartygumbez, 63+70^oC) - in the Murghab districts.

Group C. Hydrogen sulfide waters.

The healing properties of these waters are explained by the presence of hydrogen sulfide in their composition, which has significant pharmacological activity and determines the physiological and therapeutic effect of waters of this group, mainly used in the form of baths. Almost the lower limit for assigning these waters to this group is the hydrogen sulfide content of 10 mg / l . These mineral waters are found in the sources of Naspar - 36 mg / l and Garm Chashma - 170 mg / l.

Group D. The waters are ferrous, arsenic, with a high content of manganese, copper, and aluminum.

This group includes waters with a therapeutic effect determined by one or more of the listed biologically active components. As the norm for classifying waters as ferrous, the iron content is taken - 20 mg / l, and for arsenic - 0.7 mg / l of arsenic. Quantitative norms have not been established for the content of manganese, copper and aluminum in waters. There are only 2 mineral springs of this group - Miyonadara (iron - 13 mg / l) and Zoog (iron - 33-40 mg / l).

Group E. Bromine, iodine, and high organic matter waters.

To classify waters as bromic and iodine, the content of bromine is 25 mg / l and iodine is 5 mg / l, provided that the total mineralization of these waters allows them to be used as drinking mineral waters. The waters of this group are found in the sources of Shaambari and Faizabad.

Group F. Radon waters.

This group includes all waters containing more than 5 nCi / L radon. Radon water was found in the Obigarm springs 8.6 nCi / l, Rivak 78.9 nCi / l.

Group G. Siliceous waters.

This group includes siliceous thermal waters widespread in nature. A conditional norm for the content of silicic acid in them is 50 mg / l is taken at a temperature of more than 350C. Siliceous thermal sources appear in Dzhaushangoz, Tokuzbulak, Kauk, Dzhelanda, Yamchin, etc.

4. UTILIZATION OF THERMAL SPRINGS IN PAMIR REGION

The Pamirs are rich in healing thermal waters. Thousands of tourists from Tajikistan and foreign countries visit these waters every year. Especially interesting are the Garm Chashma hydropathical establishment (Photo 1), Chashmai Bibi Fotimai Zakhro in Ishkashim region and Dzhelondi in Shugnan. In recent years, on the initiative of scientists from the University of Central Asia, Khorog State University and the Pamir Biological Institute of the National Academy of Science and Technology, greenhouses and a pond for waterfowl were built on the territory of the village of Dzhelondi using water from a local thermal spring (Photo 2).

Photo 1: Garm Chashma. Bath in Pamir

Photo 2: Jelondi greenhouse (3480 m.)

Photo 3: The valley of the Modien River. **Photo 4: Lake Karakul (3914m).**

There are a lot of natural attractions in the Pamirs that attract tourists from different countries. There are several warm springs on both banks of the Modien River (Photo 3) Lake Karakul (Photo 4) is the highest salt lake in the world Ismaili Somoni(7495) and Avicenna(7114) peaks attract climbers.

The construction of highways and the improvement of the infrastructure of thermal recreation areas can lead to the creation of new jobs for the local population. Along with private one-off initiatives for the improvement of resort areas in recent years, there has been an active participation of large companies in this tourism sector. For example, the largest industrial enterprise in Tajikistan, the TALCO Aluminum Company, built a modern three-star hotel with 300 beds in Garma Chashma, which led to the development of tourism.

In 2009, the TALCO Company made a decision to create a new health and tourist complex "Somon TM", which consisted in the construction of a resort on the territory of the healing spring "Garmchashma". A 3-star hotel, a sanatorium and a family house were built based on hot mineral springs in Tajikistan. It should be noted that the health and tourism complex can receive about 240 visitors per day. The facility was commissioned in June 2010. Currently, the complex employs 40 people (season). It should be noted that during this period a line of mineral-drinking water "Narzan" (2 km) was drawn to the sanatorium. During this time, three economy-class buildings were repaired and put into operation, and within the framework of a social program, the company provided a water supply system to the nearest villages "Garmchashma" (4 km).

Another most popular thermal spring is Khoja Obi Garm located in the valley of the Varzob River, 60 km from Dushanbe. Here a thousand people annually rest, undergo balneo -, phyto - and physiotherapy. Khoja Obi Garm is a radon geothermal source.

5. FUTURE OF GEOTHERMAL ENERGY OPTIONS FOR TAJIKISTAN

Within the Alichur hydrogeological zone, the most promising from the point of view of balneology and heating are the sources of Dzhilandy and Tokuzbulak, located in the valley of the Tokuzbulak river (basin of the Gunt river). The same sources are the most promising for the organization of scientific research work (see Fig. 4)..

They are located near the Dushanbe - Murghab - Kulma - Toshkurgan (PRC) highway, 115-125 km. from the regional center Khorog.

Studies by Soviet geologists and geochemists (Zuev Y.N. etc., 1997) show that in the zone of the South Pamir fault there is an intense release of juvenile gases, among which helium, methane and nitrogen prevail. Of particular note are the high concentrations of helium found in many thermal springs. This fact allows us to consider the Pamirs as a new helium geochemical province. Helium is used in spacecraft to create excess pressure in fuel tanks, it is used in the nuclear industry, cryogenic processing, the study of superconductivity, fiber-optic cables, and liquid crystal screens. Helium enters the composition of respiratory mixtures, it is used in magnetic resonance imaging. Recently, helium has begun to be used in microelectronics to increase the recording density on hard drives.

The waters of the thermal springs carry boron, fluorine and rare alkalis such as lithium and cesium.

We believe that it is expedient to continue the remote IR survey, which began in 1979 at the Djilandy area, which would allow recording the zones of outflow faults. According to a preliminary estimate, the value of the dynamic resources of groundwater with a temperature of 60 ° C is 30 l / s.

In the Murghab-Bartang hydrogeological zone, the Elisu and Shaimak areas deserve research work. The use of thermal water for heating and hot water supply would have significant socio - economic benefits.

In the Shahdara hydrogeological zone, the most promising for use is the Langar thermal spring, the waters of which can be used both for municipal needs and for organizing a greenhouse-greenhouse economy.

Geothermal hot water reservoirs under exploration or exploitation are located in the Djilandy and Tokuzbulak areas of the Shugnan region of GBAO . These two sites are located on the right and left banks of the Tokuzbulak River, a tributary of the Gunt River, about 8 km from each other and have a similar geological structure: shallow siliceous terms that have been exploited for many years. Most likely, the basins of these sources are secondary in relation to the deep reservoir in the metamorphic basement.

In the 1980s, 10 shallow wells were drilled near natural thermal manifestations, which revealed thermal waters in the Neogene aquifer.

A deep exploration program needs to be implemented to prove the existence of deep productive horizons in the metamorphic basement. Deep exploration wells will allow us to check the existence of permeable horizons in the metamorphic basement (2500-3500 m) with high productivity, temperatures (200-300 ° C) and pressures of 4-7 MPa. It is possible that the fields of Dzhilandy, Tokuzbulak, and Javshangoz, which are now considered as separate geothermal objects at the level of not deeply deposited carbonic and siliceous springs, actually belong to the same geothermal system.

At the same time, the method of reflected seismic waves plays an important role in determining a deep geothermal object, i.e., a reliable correlation of seismic markers and permeable zones of disturbances in the metamorphic basement.

And this, in turn, presupposes the presence of accurate knowledge of the currents that are realized in geothermal reservoirs.

Geothermal sources in Tajikistan have never been considered as an energy source. Some sources (for example, Khodja Obigarm and others) were and are used only for medicinal purposes.

In Soviet times, it was believed that Tajik geothermal waters can only be used for hot water supply and district heating. The most promising for this purpose were called Shaambari, Kalayzanku, Obigarm, Yavroz,, Gumbulak, Dangara and Tebolay squares.

These deposits were located near settlements, which made it possible to carry out heating of some of these cities. For example, calculations were made according to which the resources of the Komsomolsk hydrogeological area are sufficient to heat 10 houses with simultaneous hot water supply to 30 houses with 32 apartments each.

Other sources and hydrogeological areas are generally ignored. Within the framework of the Soviet economy, when the republic's winter energy consumption was provided by imported fuel oil, coal and gas, there was no place for geothermal sources, despite the fact that many of them could be used for heating settlements.

The current state of the energy sector in Tajikistan makes us think differently about the prospects for using geothermal energy. The main reason for the current regular winter energy crises in the country is seasonal fluctuations in the level of reservoirs and, as a result, fluctuations in electricity generation.

To overcome the winter crises, it is necessary to commission power plants that do not depend on seasonal fluctuations in reservoirs. These are, first of all, thermal power plants, especially since the country has sufficient coal deposits and in this regard it is independent.

One Thermal Power Station with a capacity of 500 MWt could practically eliminate periodic energy crises.

The energy system of Tajikistan will become more resilient against external factors if the share of hydropower is reduced from 99% today to 70-75%. The remaining 25-30% can be replenished with energy from thermal or solar power plants. According to the available expert data, in order to stop importing electricity, Tajikistan needs to additionally produce about 3 billion kWh of electricity in the autumn-winter period. The thermal power plant on coal with a capacity of 500 MWt is capable of producing up to 2 billion kW / h per season (October-March). The production of another 200 million kW / h of electricity may well be assigned to the GeoPP. For this, the total capacity of the stations of 30 thousand kW is sufficient, which will provide an output of 220 million kW / h during operation for 7400 hours.

The cost of such a GeoPP with the use of Israeli equipment will be about $ 60 million, with the use of Russian equipment - $ 211 million.

It is worth noting that it is necessary to create a whole complex around geothermal sources, in which the energy and heat of the underground will be a source of electricity.

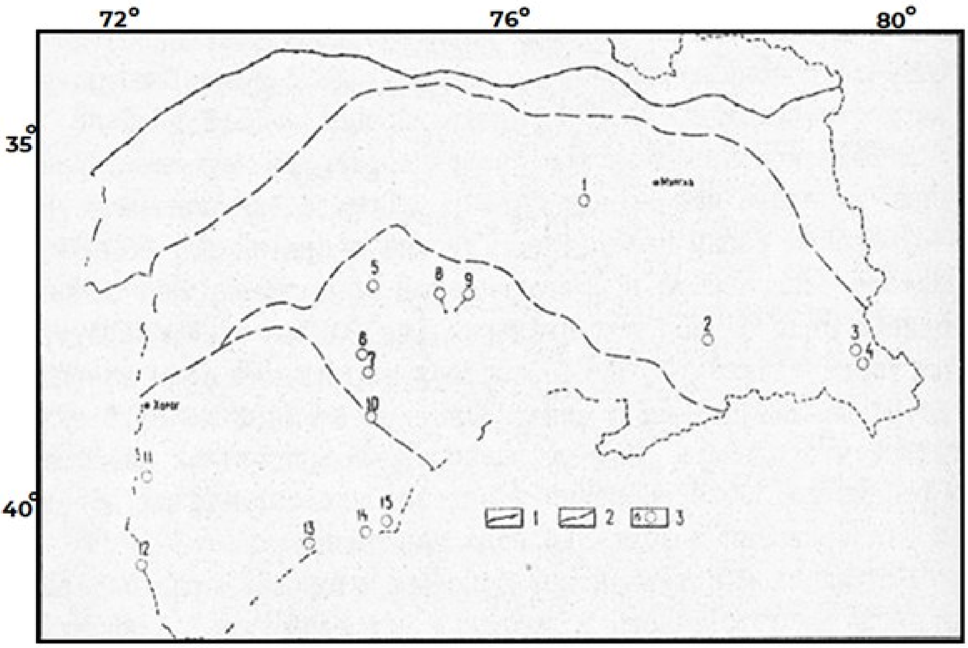

Figure 4: Schematic map of the distribution of thermal waters within the South Pamir hydrogeological array 1-boundaries of the hydrogeological array; 2– boundaries of hydrogeological zones; 3-manifestation (source) of thermal waters and its number.

REFERENCES

https://worldpopulationreview.com/countries/tajikistan-population

Bernd Schurr, etc., Seismotectonics of the Pamir, AGU Publications, Potsdam, Germany (2014).

Ilolov M., Kuchakshoev Kh.S., Khudonazarov A.M. On the deep geothermal system of the Southern Pamirs and its potential, Nuri Marifat, Khujand, Tajikistan (2015).

Krat V.N. Mineral medicinal, thermal and industrial underground waters of Tajikistan, Donish, Dushanbe (1985).

Petrov V.N., Akhmedov Kh. M., Kabutov R., Karimov Kh.S. Renewable Sources of Energy in Tajikistan.

News of the Academy of Sciences of the Republic of Tajikistan, Department of Physical-Mathematical, Chemical, Geological and Technical Sciences, Donish, Dushanbe (2009).

https://chrdk.ru/sci/intervyu-alekseenko

Statistical Yearbook of the Republic of Tajikistan, Tajstat, Dushanbe (2018).

Bobokhojaev I.Y., Davlatmamadov Sh. Therapeutic Mineral Springs of the Pamirs, Dusahbe (2010).

Ivanov V.V., Nevraev G.A. Classification of Underground Mineral Waters, Nedra, Moscow (1980).

Zuev Y.N. etc. Energy Mode of the Earth's Crust in Central Asia, Nauka, Moscow (1997).

APPENDIX: STANDARD TABLES

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

[1] I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

	Locality	Type[1]	Maximum Utilization Flow Rate (kg/s)	Temperature (°C) Inlet	Temperature (°C) Outlet	Enthalpy[2] (kJ/kg) Inlet	Enthalpy[2] (kJ/kg) Outlet	Capacity[3] (MWt)	Annual Utilization Ave. Flow *	Energy[4] (TJ/yr)	Capacity Factor[5]
	Central Tajikistan										
1	Khoja-Obigarm	B	1.5	98	35			0.395	1.400	11.634	0.933
2	Tamdikul	B	0.65	88	38			0.136	0.650	4.287	1.000
3	Havatag	B	11.30	55	25			44.714	11.000	43.527	0.031
4	Obi-Garm	B	14.8	53	24			1.796	14.000	53.551	0.946
5	Obisafet	B	12	51	24			1.456	11.000	39.174	0.853
6	Garmova	B	1.3	42	18			0.158	1.250	3.957	0.795
7	Yavroz	B	9	41	17			1.092	8.500	26.908	0.781
8	Yamankyrchin	B	3	33	12			0.364	2.750	7.617	0.664
	Pamir										
9	Kauk	B	4	76	34			0.703	3.800	21.051	0.950
10	Issykbulak	B	1.5	71	33			0.238	1.450	7.268	0.966
11	Jilandy 1	B	5.6	67	32			0.820	5.500	6.182	0.239
12	Jilandy 2	H	8	69	29			1.339	7.000	8.879	0.210
13	Jilandy 3	F	9	76	30			1.732	8.000	48.539	0.889
14	Tokuzbulak 1	B	2	66	30			0.301	1.750	8.310	0.875
15	Tokuzbulak 2	H	4	60	25			0.586	3.750	17.312	0.937
16	Elisu	B	1.5	63.5	27			0.229	1.450	6.981	0.966
17	Jartygumbez	B	3.5	60.5	28			0.476	3.500	15.004	1.000
18	Garmchashm	B	1.5	60	24			0.226	1.400	6.648	0.933
19	Langar	B	1.5	49	20			0.182	1.400	5.355	0.933
20	Yamchun	B	3	43	19			0.301	2.800	8.864	0.933
21	Kokbai	B	4	40	17			0.385	3.850	11.680	0.962
22	Bakhmyr	B	0.4	38	15			0.038	0.400	1.213	1.000
23	Kyzylrabat	B	1.6	38	16			0.147	1.550	4.498	0.968
24	Jaushangoz	B	10	36	14			0.920	9.000	26.116	0.900
25	Shirgin	B	6	35	13			0.552	5.500	15.960	0.916
26	Shakhdara	B	12	35	15			1.004	11.000	29.018	0.916
27	Avj	B	4.2	34	12			0.387	4.000	11.607	0.952
28	Koytezak	B	1.5	33	12			0.132	1.250	3.462	0.833
29	Sasykbulak	B	2	32	13			0.159	1.850	4.636	0.925
30	Khanyuli	B	5.7	32	12			0.477	5.600	14.773	0.982
31	Darshai	B	2.3	31	12			0.183	2.250	5.639	0.978
TOTAL			148.35	1606	675			61.630	138.600	479.649	0.844

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W
since projects do not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]	1.925	26.191	1.147
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming	1.732	3.657	0.889
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	57.973	449.801	24.130
Other Uses (specify)			
Subtotal	61.63	479.649	26.166
Geothermal Heat Pumps			
TOTAL	61.63	479.649	26.166

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Prograr
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	20	40	40	0	0	20
2016	25	43	42	0	0	25
2017	24	45	41	0	0	25
2018	30	42	40	0	0	26
2019	35	41	43	0	0	24
Total	144	211	206	0	0	

TABLE 8.	TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$					
Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.200	0.300	1.0	0	20	80
2000-2004	0.250	0.350	1.200	0	18	82
2005-2009	0.300	0.400	1.300	0	25	75
2010-2014	0.310	0.400	1.500	0	24	76
2015-2019	0.330	0.390	1.400	0	20	80