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Possibilities of Increasing the Efficiency of Use of Geothermal Resources on the Basis of Energy-Biological Complexes

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ABSTRACT

The most powerful natural thermal water resources of the Caspian region are located in the Republic of Daghestan. Thermal waters are widely used here for heating and hot water supply. But this region has been depressed in recent years and development of the geothermal program was practically stopped and at present it requires the full modernization of obsolete technologies. The company JSC "Geotermneftegas" is the only one in Russia with more than 10 licenses for the right of geothermal heat-carrier production. The other enterprises have either disintegrated or use foreign credits. The company is also an owner of the licenses for geological exploration and production of hydrocarbons in the Caspian shelf, the forecasted resources of which are 340 million tons of oil and 540 billion m^3 of gas and gas-condensate.

Production of such volume of raw materials will lead to losses of biological resources of the sea, where 90% of the world sturgeon reserves with total value of about $5 billion are concentrated. Taking all this into account, in the paper the main attention is paid to elaboration of preventive compensation measures, in particular, creation of energy-biological complexes (EBC) on geothermal waters for the reproduction and restoration of the resources of sturgeons – representatives of relict ichthyofauna.

The conception of integrated geothermal systems, realized when developing the described EBC, is directed to solving the main problems of the Republic: creation of new work-places, keeping of Russian population in the territory of their permanent residence, improvement of the quality of life and health of the population, and protection of a unique nature of the region.

This project will support the economics of Daghestan, adding stability to the policy of reform. Realization of the project will supply the population with high quality food (fish, fish-products, poultry and vegetables). Application of complex technologies will give the opportunity to use thermal water for electric power production and balneology. In the paper a brief description is given of the situation with power in the Republic of Daghestan.

It is shown that development of systems of geothermal water supply and of energy-biological complex have prospects. The most interesting financial results and schematic solutions realized for elaboration of the business-plan of investment project "Creation of energy-biological complex on the basis of explored geothermal resources of the Northern Daghestan" are presented.

INTRODUCTION

Large scale, possibility of complex utilization and production by modern technical means are the peculiarity of geothermal energy.

From a global aspect, resources of geothermal energy at depths available for development (up to 5 km) are sufficient for work of all thermal electric power stations of the world for 100,000 years. In utilitarian aspect, reserves of thermal water all over the CIS are more than 20 million cubic m/day (the lowest estimation) for work of geothermal circulating systems and 1 GJ of obtained heat is 1.5-2.5 times cheaper than that produced by thermal power stations and boiler-houses.

Taking this into account together with the significant explored resources, geothermal power engineering may be considered a priority direction of the Russian economy.

Although now the main directions of thermal energy utilization are formed, that is: electric power production, industrial and municipal heat and water supply, balneology, green-houses, valuable microelements extraction - the real sphere of possible application of geothermal water is wider. To confirm it, we represent the diagram of complex utilization of geothermal water in different technological processes (Fig. 1).

In our opinion, just this factor in future will become dominant when developing the resources of isolated and distant fields, since it will permit the essential improvement of the economy of geothermal production.

It is necessary to note that now many practical questions, connected with creation of geothermal circulating systems, prevention of corrosion and saline depositions, injection back of used geothermal water, have already been solved.

The Republic of Daghestan (RD) is situated at the northeast slope of the Central Caucasian Range. It borders on five foreign States and occupies key economic and geographical position in the South of Russia. In the East, the territory of Daghestan is washed by the Caspian Sea. Mountains occupy more than 50% of the area and the lowland – up to 44%. Daghestan is the largest (50300 sq km) and most populous republic of Russia. Now the population makes up 2.5 million people (1.3% of the population of Russia), including 1.5 million of the country people. The climate of Daghestan is, mainly, moderate-warm and continental. The temperature regime of the lowland part of the Republic is rather favorable for plant-growing and cultivation of different heat-loving cultures.

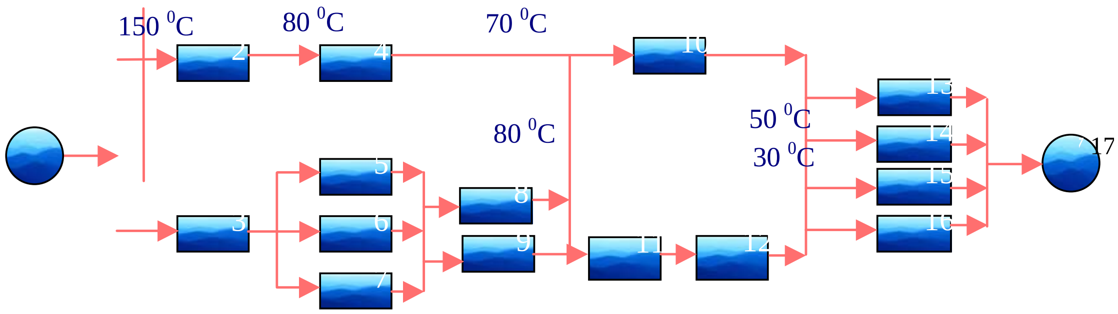

Fig. 1. Basic integrated diagram of geothermal water utilization: 1 - producing well; 2 - electric power production; 3 - refrigeration; 4 - central heating and (or) hot water supply; 5 - industrial processes; 6 - sawmills; 7 - foodstuffs production; 8 - green-houses; 9 - grain drying; 10 - dehydration; 11 - fodder production; 12 - heat pump; 13 - soil heating and (or) irrigation; 14 - fish breeding; 15 - chemical production; 16 - balneology and bathing; 17 - injection well.

Table 1: Production of basic food per head in the Republic of Daghestan

Name of products	Years							Living wage	Medical norm	Percent of provision
	Mean annual size of the population, thousand people									
	1986-1990	1996	1997	1998	1999	2000	2002			
	2000	**2073**	**2094**	**2120**	**2142**	**2160**	**2200**			
Grain, kg	264	148	132	94	124	108	168	1000	1000	17
Flour, kg	62	35	20	11,5	16	5	5	187	137	3,6
Meat, kg	67	51	55	55	46	49	25	36	70	35
Milk, kg	192	122	125	125	125	125	141	196	360	39
Potatoes, kg	43	75	51	48	58	48	95	100	97	98
Vegetables, kg	125	61	58	120	180	143	225	97	165	136
Fruit, kg	207	107	92	43	43	48	50	19	80	62
Fish, kg	18	10	8	7	10	7	2	11	18	11
Eggs, pieces	131	70	90	102	105	113	134	180	243	55

However the social-economical development of the Republic in recent years with a sharp deficiency in the use of indigenous fuel resources (almost 100% of solid fuel and up to 60% of natural gas are imported) resulted in lowering of the living standard in comparison with the rest of Russia. So, average salary in Daghestan is 2.7 times lower than in Russia as a whole, and unemployment is 1.8 times higher.

Economic difficulties and large demographic variability are causing social tension in the region and a low standard of life of the population. In addition, the decrease of production and consumption of the most valuable foods: meat, milk, eggs, fish is appreciable. In 2002 only 25 kg of meat per head was produced, which was 2.8 times less than the physiological norm. In recent years this tendency has increased even more, which is demonstrated by the statistics (see Table 1).

Recently an unfavorable power situation for development of agriculture has developed in the Republic. This may be seen especially by example of the enterprises, placed in the Northern Daghestan and focused on almost 100% consumption of natural gas. Under this condition, any interruptions in energy supply of the enterprises, which have the sole purpose of immediate profitability, resulted in serious consequences. For example, interruption of gas delivery in December 1997 for three days in the poultry farm “Oktjabrsky” resulted in material damage of 56 million dollars.

Daghestan possesses different kinds of energy resources. Oil, natural gas, hydroelectric power, geothermal power, solar energy, wind power are the main resources. Practically all of the electric power of the Republic is produced by hydroelectric power stations (by central heating plants less than 3%). Resources of oil and natural gas of Daghestan are significant, but considerable financial credits are required, which the Republic does not have, to increase their production.

Daghestan exports all extracted oil and part of its electric power, produced by hydroelectric power stations. In 2000 the export of power resources from Daghestan was about 25% of their total production.

Since oil and electric power as a fuel do not take part in fuel-energy balance, this leads to a necessity to import significant quantity of energy resources, such as oil products, natural gas, coal and firewood. In 1994 their quota in total consumption was 41%, and in 2000 - 50%. It demands to use all available local energy resources.

In future, Daghestan intends to reduce the oil export and import of oil products gradually. Besides, there is a possibility to increase significantly the quota applied in natural gas for housing, electric power and renewable energy sources (RES).

Daghestan is rightly considered a geothermal province of Russia and the pioneer in development of deep underground heat in the USSR, it has unique reserves of non-polluting and renewable energy, which if fully used may be 50% in the fuel-energy balance of the country.

Capacities of the company "Geotermneftegas" allow it to carry out, on a wide industrial scale, all works connected with geological exploration, production and realization of geothermal water in the territory of the Republic of Daghestan. These include: drilling of exploratory and development wells, construction of areas of production and transportation of geothermal heat-carriers, and building of energy-biological complexes. Resources of geothermal water amount to 2.2 million cubic meters/day, which in heat equivalent (60 million GJ) is fully comparable with the volumes of fuel-power resources (3.2 million TRF), consumed annually in the Republic.

At present in Daghestan, 17 fields of saline and heat power waters have been explored and more than 120 wells have been drilled, 53km heat pipelines and 7 heating and pumping stations have been built.

There are no geothermal power plants in Daghestan, therefore the thermal waters are used mainly for heat supply and particularly for mineral water bottling and balneology. Nowadays capacities of geothermal heat supply systems are 32.2 MWt and other systems of the same capacity are planned in Makhachkala and Kizlyar towns. In 2002 the company "Geotermneftegas" produced 613 thousand GJ of heat power that provided heat and hot water to more than 100 thousand consumers in the towns of Kizlyar, Makhachkala, and Izberbash. Hot water supply to sanatoria and recreation zones in the territory of Daghestan is also provided by geothermal water. Geothermal heat sources are quite competitive and significantly cheaper than traditional heat-carriers. The average cost 1 Gcal of geothermal heat now is $4.7 which is 35-50% cheaper than heat obtained from gas boilers.

However it is necessary to note that with transition to market economics and the suspension of prospecting works financed from the federal budget, the first serious difficulties have appeared in the maintenance and functioning of geothermal complexes already created. Increase of natural gas delivery to the Republic from the main pipelines has intensified this situation. Thus, contrary to expectations, the sharp rise in prices of gas and traditional energy carriers has not stimulated an adequate increase of demand for geothermal energy; instead a falling-off in production has taken place.

The scale of this falling-off may be illustrated in the following figures: in 1988 geothermal water production on the Board "Dagburgeotermija" reached 11.3 milion m^3, in 2002 it was only 3.6 million m^3, i.e. a decline of 60%.

The present-day situation in this sphere is characterized by the absence of any increment of geothermal water reserves, low demand for geothermal heat produce and, as a consequence, by an increase of numbers of idle wells and fields, especially in regions remote from large populated areas. So, the experience of preceding years has shown that the geothermal branch of the economy without State support cannot play significant part in energy balance of the Republic.

The most extensively explored geothermal resources with temperatures 40-107^{0}C and mineralization range from 1.5 - 27 g/l are concentrated in the northern region of Daghestan. From the 1960s until the present day, ten fields have been discovered here, 64 wells have been drilled and prepared for exploitation. Some of the wells are used already for heating of Kizlyar town and a number of villages in this region. Concerning other wells, they are far from large settlements, which does not allow exploiting them for district heating. For this reason these wells are put in dead storage.

In this connection we have made analysis of the idle explored deposits of the northern region of Daghestan to determine the most prospective of them for creation of the first energy-biological complex (EBC). It is established that the Rechninsky field is an ideal one for demonstration of an opportunity of wide complex utilization of geothermal water in agriculture. This field is located in the territory of the "Oktyabrsky" poultry state farm and is 7 km distant from Kizlyar town along a good asphalt road. The geographic coordinates of the deposit centre are the following: latitude 43^0 51' north, longitude 46^0 43' east, absolute height from -5 to -7 m. The deposit territory is placed in a waterless zone of semidesert and characterized by a continental climate. Summer is dry and hot with maximum temperature in July up to +40^{0}C. Winter is moderately cold with the lowest temperature -20^{0}C. The duration of the heating cycle is 180 days. Reference temperature of external air for heating system is -17^{0}C. Duration of solar radiance is not less than 2000 hours per year. Annual precipitation is 300 mm. Northeast and southwest winds prevail here. Rechninsky deposit is 13 km distant from the railway station Kizlyar and 150 km distant from the capital of the Republic. There are six wells prepared in readiness for exploitation, which have yielded powerful inflows of thermomineral waters from chokhrak, akchaghyl and apsheron deposits as a result of tests. Discharges of wells amount to 3000 cubic meters/day at gauge pressure 0.9 – 1.0 MPa and discharge temperature 40-105^{0}C. Development work proves the possibility of full reinjection of all utilized geothermal heat-carrier at comparatively moderate (2-3 MPa) discharge pressures also. It is necessary to finish the detailed exploration of the field with calculation of commercial reserves. These operations are executed simultaneously with deposit exploitation under conditions approximated to the operating ones.

After analysis of experience of EBC creation at nuclear power plants in Russia and other countries (USA, Germany, France) we have reached a conclusion that the use of thermal water allows us to increase significantly the profitableness and reliability of the Complex and expand the operation range of heat potential of geothermal water. Actually, by their temperature and quality the waters are most suitable for utilization in the hot water heating and ventilation and hot water supply systems of green-houses, hotbeds, poultry farms and fish-ponds, i.e. for growing under artificial conditions useful foodstuff such as vegetables, poultry and fish, chlorella and other byproducts (see Table 2). Low mineralization of the water and absence of phenol in it are favorable to this purpose. Moreover the problem of emergency release of used water along the bed of the river Gorodskoy Bank and numerous irrigation canals (Kislyar - Caspian, Novoterechnyi and other), which are practically waterless in winter, is solved. The existence of settlements within a radius of 1-5 km from the designed complex is an additional advantage of the chosen deposit. There are trained personnel to operate the EBC in these settlements. The neighborhood of Kizlyar allows delivering the grown production to consumers. If needed, there is a real possibility to obtain a considerable additional amount of thermal water by new drilling.

Table 2: Comparative parameters of fresh water quality for fish breeding

№	SUBSTANCE	MpC		Parameters of geothermal water quality				
		fresh	for fish	Rechninskaja	Kordonovka	Thernair	Isberbash	Karaman
1	Depth of drilling, m			1720	1106	1240	1555	2000
2	Aquifer			Continental	Apsheron	Karagan,1s.	Tshokrak,	Aktshagyl
3	Flow rate of well,			620	2500	1440	700	260
4	Head on wellhead, MPa.			0,04	0,6	0,2	0,3	0,5
	1.Generalized parameters							
5	Temperature, ^{0} C	7-11	20-28	45	40	48	45	40
6	Colourness	< 30	< 30	Colorless	Yellowish	Colorless	Colorless	Colorless
7	Transparence, sm	30	30	Transparent	Transparent	Transparent	Transparent	Transparent
8	Smell, grade	No > 2	No > 2	Oil	Without	Without	Without	Oil
9	Taste and smack, grade	No > 2	No > 2	Salt	Fresh	Fresh	Fresh	Salt
10	pH	6-9	6-8	6,78	8,4	7,43	7,24	8,6
11	Mineralization total, g/l	1-1,5	10-18	23,5	2,5	5,0	1.4	8,3
12	Alkalinity, mg-eqv/l	2	2	3,5	19	10,8	8,1	8,1
13	Hardness total, mg-eqv/l	7-10	8-12	40,7	0,98	2,6	6,0	3,77
14	Oxidisability, mg O_2/l	5	5-20	9,9	60,8	2,3	1,04	30,4
15	Oil products total, mg/l	0,1	0,05	Not deter.	Not deter.	Not deter.	Not deter.	Not deter.
	2. Inorganic substances							
16	Sulfates (SO_4^{2-}), mg/l	500	100	18,7	22,2	1455,9	411,5	70,8
17	Chlorides (Cl^-), mg/l	350	300	14111,7	524,4	1165,5	102,4	4560
18	Phosphates, mg P_2O_5 /l	0,2	0,2	0,02	Not found	0,05	0,01	Not deter.
19	Lead (Pb^{2+}), mg/l	0,03	0,1	Not found	0,007	Not found	0,009	Not found
20	Zinc (Zn^{2+}), mg/l	5,0	0,05	0,065	0,622	0,059	0,015	0,015
21	Nitrogen ammonal, mg/l	0,5	0,5	19,44	1,5	0,55	2,33	Not deter.
22	Nitrogen nitrital	0,02	0,02	Not found	Not found	Not found	Not found	0,02
23	Nitrogen nitratal	9,1	9,1	Not found	Not found	Not found	Not found	1
24	Iron (Fe), mg/l	1,0	0,05	20,2	76,6	0,9	5,2	1,7
25	Calcium (Ca^{2+}), mg/l		180-610	518,6	8,1	31,2	66,8	27,7
26	Magnesium, mg/l	50	50	181	7	13,4	33	29
27	Copper, mg/l	1,0	0,005	0,034	0,1	0,004	0,003	0,005
28	Manganese (Mn), mg/l	0,5	0,05	Not found	1,8	0,06	0,21	0,069
29	Selenium (Se^{6+}), mg/l	0,01	0,0016	Not found	Not found	Not found	Not found	Not found
30	Strontium (Sr^{2+}), mg/l	7	10	3,4	2,5	1,6	1,6	4,7
31	Mercury (Hg^{2+}), mg/l	0,0005	0,0005	Not found	Not found	Not found	Not found	Not found
32	Arsenic (As^{3+}; As^{5+}),	0,05	0,05	0,1	0,01		0,008	0,16
33	Fluorine (F), mg/l	0,05	0,05	1,2	1	0,5	1	1
34	Chromium (Cr^{6+}), mg/l	0,05	0,02	Not found	Not found	Not found	Not found	Not found
35	Nitrates (NO_3), mg/l	45	40	Not found	10	Not found	Not found	1
	3. Organic substances							
36	Bitumen neutral			1,5	1,5	2,3	0,8	1,4
37	Bitumen air-blown			1,4	5	2,9	1	4,2
38	Humus			6	57,5	3,1	2,8	32,9
39	Phenols, mg/l	0,001	0,001	Not found	Not found	Not found	Not found	Not found
40	Aromatic hydrocarbons,	0,5	0,5	Not found	0,425	Not found	1,1	Not found
41	Volatile acids, mg/l	4	4	Not found	Not found	Not found	Not found	Not found
42	Naphtenic, mg/l	1	1	Not found	Not found	Not found	Not found	Not found
	4. Gases							
43	Oxygen (O_2), mg/l	No < 4	No < 6	Not found	Not found	Not found	Not found	Not found
44	Carbon dioxide (CO_2),	To 10	To 10	96	Not found	150	200	Not deter.
45	Hydrogen sulfide (H_2S),	0,003	Absence	Not found	Not found	Not found	Not found	Not found
46	Methane (CH_4), mg/l	2	Absence	264		Not found	33	
47	Chlorine free, mg/l	0,5	Absence	Not found	Not deter.	Not found	Not found	Absence
48	Nitrogen free, mg/l	0,085		Not deter.	Not deter.	Not found	Not deter.	Absence
49	Nitrogen dissolved, %			38,7	1,15	52,9	66,1	Absence
50	Mixture of spontaneous			CH_4+N_2	Not deter.	N_2 -97%	Not deter.	CH_4 -97%
51	Mixture of dissolved gas			N_2+CH_4+CO	CH_4+CO_2+N	N_2+CO_2	N_2+CO_2+CH	CH_4+CO_2
52	Gas saturation, ml/l			7,08	13,05	Not deter.	5,4	14,44

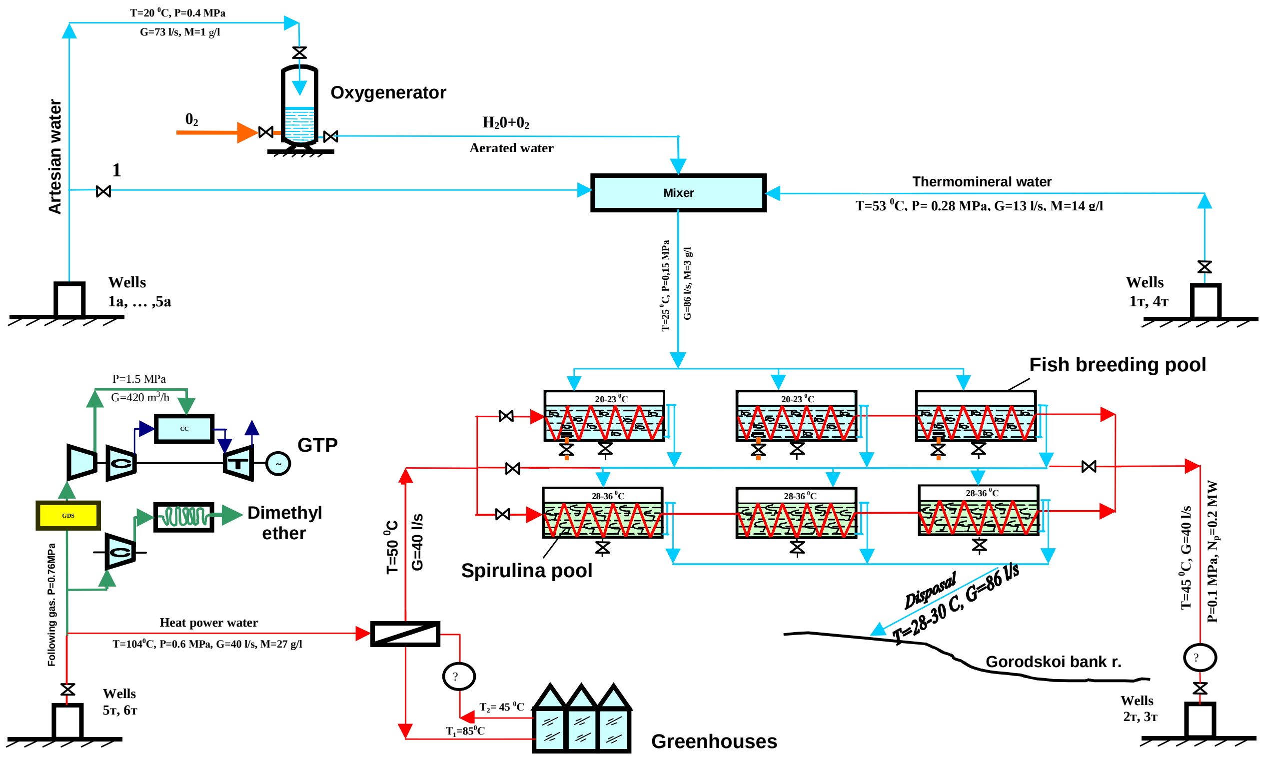

Fig. 1. Diagram of Rechninsky energy-biological complex: 1 – crosspiece; 2 – emergent delivery of oxygen into pools through sprays

In connection with transition to the market relations, it appears that at present the advantage in organization of geothermal production must be revised in favor of agriculture. It is caused, first of all, by the local character of underground heat utilization, which dictates the development of fast circulating and fast payable production, the placing of which near the thermal water intake are economically feasible. Taking into account that now any new building may be built only by means of credits, it is necessary to choose such a direction of geothermal water utilization and such forms of organizational structures, that would guarantee a maximal profit to investors. This condition is of great significance because it opens possibilities for private business in the sphere of geothermal production.

In recent years, a significant work has been done for substantiation of this new direction in geothermal activities and adaptation of existing technologies of energy-biological complexes to conditions of geothermal fields. Results of this work have found the most complete realization in the business-plan of investment project, elaborated by JSC "Geotermneftegas". It includes the autonomous geothermal power plant (GPP) with capacity 0.7 MWt, fish-ponds and pools (35 hectares) for growing 25 million specimens of sturgeon fry, 1150 tons of marketable sturgeons and 1500 tons of chlorella and spirulina, green-houses and heated ground under polyethylene film (5.3 hectares) for growing 5040 tons of early vegetables (for the cycle), poultry-house for 54 thousand of broilers and unit for production of dried yeast (20 tons). Besides, surpluses of associated gas are used to manufacture non-polluting liquid fuel - dimethyl ether (see Fig.1).

One can see that the orientation to maximal use of heat and water resources of geothermal field and chemical energy of associated gas and also introduction of intensive biotechnologies are the features, which will allow to raise commercial profit significantly by producing the valuable food.

In addition, possibilities of building and operation of the EBC working on geothermal water are essentially higher than when using waste waters of electric power stations, which contain different organic pollutants causing anomalies of fish development. In contrast, geothermal waters are sterile, have increased operational reliability, high temperature potential, constant temperature and flow rate and also free heads, sufficient for transportation over significant distances without pumping. They are also an excellent culture medium for production of vitamin fodder, baking yeast, microgreens chlorella and spirulina.

The possibility of year-round operation of the geothermal EBC without use of commercial heat in winter is a very important advantage in comparison with EBC at nuclear electric power stations. As the experience of fish breeding in warm water shows (the Kostroma, Tver and Tula regions, the Republic of Udmurtiya), this method provides sufficiently intensive growth of all of sturgeon juveniles, permits to reduce the period of maturing of spawners by a factor of two, to provide their yearly spawning and to obtain marketable produce already in the second year of cultivation. Productivity of fish-ponds and pools heated with thermal water is increased by one order and the mass of two-year old specimens of sturgeon can reach 2-3 kg and more (references 1-3).

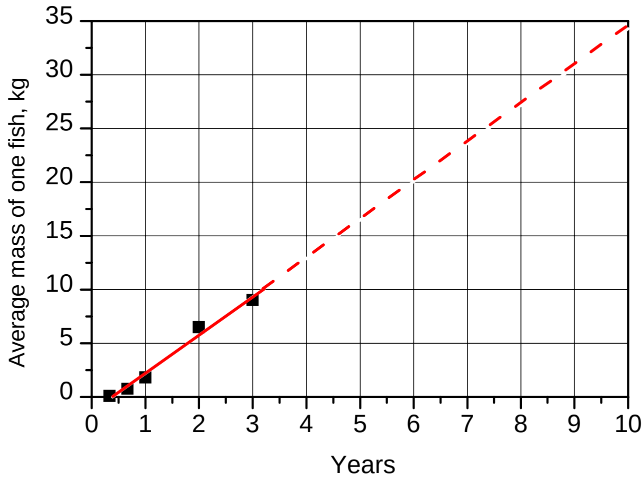

Fig. 2. Dynamics of marketable sturgeon growth in fish-ponds and pools, heating with geothermal water with control of thermal mode

As a basis of the linear approximation shown here (see Fig.2) the experimental data were taken from reference 4.

The working project of the first turn of the construction foresees creation of a complete hatchery with open and closed pools and stationary fish-ponds filling with warm mineral water (23-25^{0}C). Sturgeon growing lasts for two years, which permits to bring fish to the standard marketable mass of 2 kg suitable for use as a food. It is contemplated that the second turn can realize more promising long-term rotation with the purpose to obtain the commercial caviar at the end of the production cycle. It considerably increases the efficiency of the EBC, because demand for caviar is practically unlimited and it is 10 times higher in price than the meat of fish.

The unit for growing of chlorella and spirulina represents open, round pools with the depth 0.5 m and area 0.1 hectares, with a total number 200.

In such units, during the vegetation period from 15 of May until 15 of September, from one hectare of aquatic surface one can obtain 800-1000 cubic meters of suspension with density 20 million cells/ml that when evaluated in dried substance of chlorella makes 5-7 tons. As culture medium for intensification of their growth, the geothermal water from well № 6т, drilled in chockrak aquifer and from fish breeding unit of the EBC is used. Thermal water from this well is characterized as silicate boric chloride-sodium, neutral reaction with mineralization 18 g/l, temperature 104^{0}C, pH 6.9, it contains CO_2 0.47 g/l and wide scale of macro- and microelementts, required for effective cultivation of aquatic plants in artificial conditions. After filling in pools with water they are sowed with a culture of chlorella counting 340-350 g of microalgae on 1 hectare (proceeding from dry weight). Gathering is begun when density of green biomass reaches 5 cm^3/1, which proceeds approximately 1 g/l of dried biomass. Further suspension taking from pools is subjected to filtration, centrifuging, sedimentation, drying and milling.

Dried biomass is milled to condition of marketable produce and packed in sacks for dispatch to consumers.

Output of biomass, grown on geothermal water is two times as much and – by biochemical indices – as good as biomass obtained on known culture mediums (Tamija, Zarruck and so on). High productivity of chlorella in geothermal water is due to the presence of easy assimilable salts, microelements, CO_2 and optimal pH of the medium. Besides, insufficient changing of temperature and chemical mixture of water do not influence intensity of growth of the cells in suspension. At the same time, availability in the water of constructional elements from copper and other heavy metals, rubber and so on negatively influences the growing of chlorella cells.

One can note that the process of growing cells of chlorella refreshes the geothermal water and also cleans it of some harmful admixtures, phenols among them (see Fig.3).

The cost of vitamin-mineral additions obtained from dried biomass of chlorella now is $330/kg. For some information, cost of preparations from spirulina reaches $100/kg and for raw material of chlorella - $30 that testifies to existence of high demand for this product.

Summary volume of investments required for realization of the project is estimated $16 million, including buildings and constructions - $11.43 million.

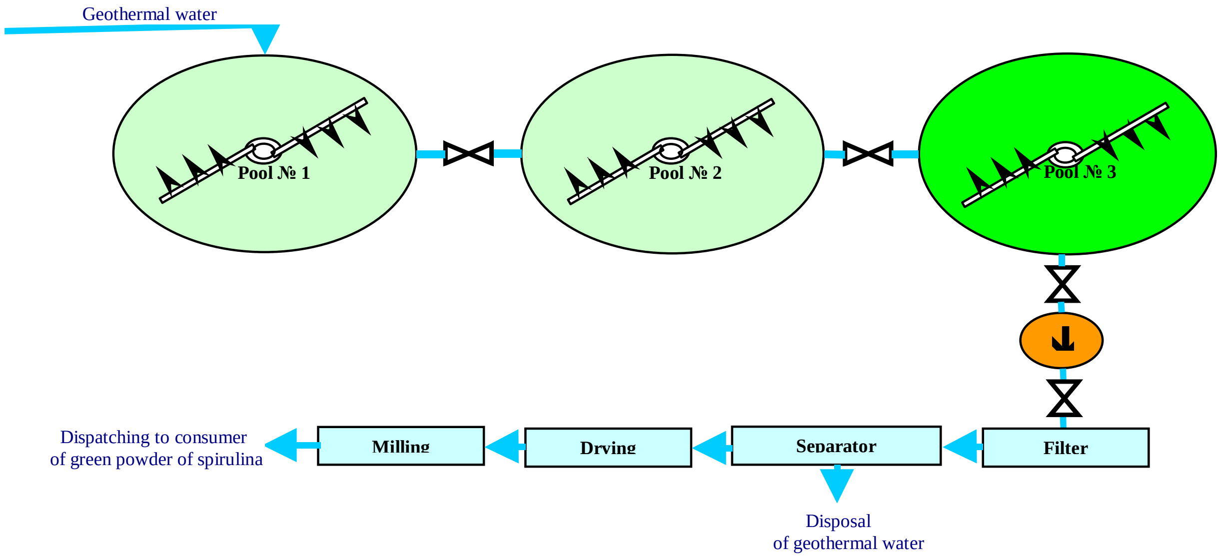

Fig. 3. Diagram of cleaning the geothermal water from phenols with output of dried mass of spirulina

The total prime cost of finished production of the EBC is \$12.86 million, including: expenses for salary - \$2.0 million (15.55 %), material expenses - \$6.16 million (47.9 %), amortization - \$1.141 million (8.87 %), taxes and other obligatory payments \$3.559 million (27.68).

Given in Table 3, technical-economical parameters testify to high level of economical efficiency of the project: profitableness of the capital - 12.5 %, profitableness to the cost - 304%, net present value (NPV) - \$35 million, internal rate of return (JRR) – 27 %, profitability index (PI) - 3.2, payback period (PP) - 3 years from output of the first production and 6 years from start of financing. Income of the enterprise for design period 4.5 times exceeds exploitation cost, i.e. the EBC is a highly paying production.

Realization of the project will make additionally 500 new work-places and will provide revenues to the budget of the Kizlyar district of \$3.3 million annually, i.e. the EBC is a socially significant investment project.

At present it is a unique geothermal project, which has been passed the competitive selection and the State examination in the Ministry of Building, the Ministry of Agriculture, the Ministry of Natural resources and the Ministry of Economics of the Republic of Daghestan.

CONCLUSIONS

1. On the basis of studying the technologies of energy-biological complexes at thermal and nuclear electric power stations, a new concept has been formulated and substantiated for the development of geothermal resources of explored fields. This concept permits the solution of the problem of sturgeon reproduction and damage compensation, caused to the biological resources of the Caspian Sea as a result of the development of hydrocarbon resources in licensed shelf blocks.

2. Use of geothermal water in energy-biological complexes allows the creation of a continuous production process of sturgeon youth and marketable sturgeon growing. Simultaneous sterilization of water is provided, risks of production and power consumption are reduced, which permits a shortening by 1.5-2 times the process of growing and maturing of spawners in comparison to natural conditions. Regulated conditions of growing allow acceleration of the process of production of other types of delicacies - balyk, reproduction and food black caviar.

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Table 3: Comparative parameters of fresh water quality for fish breeding

Parameters	UNIT	Total	Including on years									
			2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1. Volume of loan capital*, including:	$ thous.	16000	5030	6520	4450	-	-	-	-	-	-	-
- investments in fixed capital	“	11430	3430	5720	2280	-	-	-	-	-	-	-
- investments in circulating capital	“	4570	1600	800	800	1370	-	-	-	-	-	-
2. The cost of production:	“	12860	-	-	-	1370	1520	1588	1676	1727	1863	3116
- planting material, raw material, fodder, completing,	“	6160	-	-	-	670	720	780	852	895	990	1253
- expenditure for salary	“	2000	-	-	-	248	292	292	292	292	292	292
- depreciation charges	“	1141	-	-	-	163	163	163	163	163	163	163
- taxes and other payments	“	3559	-	-	-	289	345	353	369	377	418	1408
3. Liquidation cost	$ thous.	10289	-	-	-	-	-	-	-	-	-	10289
4. Production volume in natural expression	tons	11575	-	-	-	1300	1360	1580	1600	1650	1700	2385
- sturgeon youth (120 g)	thous. pieces	25000	-	-	-	2500	2500	4000	4000	4000	4000	4000
- meat of sturgeon	tons	1150	-	-	-	90	325	450	645	825	1000	1150
- black caviar unpressed	“	60	-	-	-	-	-	-	-	-	-	60
- balyk of cartilaginous fish	“	575	-	-	-	-	-	-	-	-	-	575
- spirulina and chlorella	“	1500	-	-	-	80	140	180	200	250	300	350
- early vegetables	“	5040	-	-	-	720	720	720	720	720	720	720
- other products (poultry, yeast, organic fertilizer)	“	1400	-	-	-	200	200	200	200	200	200	200
5. The total receipts from produce realization	$ thous.	128200	-	-	-	9500	11300	16250	16850	18350	19850	36100
- sturgeon youth	“	62500	-	-	-	6250	6250	10000	10000	10000	10000	10000
- black caviar unpressed	“	9000	-	-	-	-	-	-	-	-	-	9000
- balyk of sturgeons	“	5750	-	-	-	-	-	-	-	-	-	5750
- spirulina and chlorella	“	45000	-	-	-	2400	4200	5400	6000	7500	9000	10500
- early vegetables	“	5040	-	-	-	720	720	720	720	720	720	720
- other products	“	910	-	-	-	130	130	130	130	130	130	130
6. Receipts from realization of produce	$ thous.	106834	-	-	-	7916	9417	13542	14042	15292	16542	30083
7. Financial result	“	105633	-	-	-	6546	7897	11954	12366	13565	14679	38626
8. Repayment of received investments	“	23600	1600	800	800	800	800	800	4800	4600	4400	4200
9. Net present value (NPV)	$ thous.	35049	-5030	-6331	-4201	3926	4684	7089	4578	5279	5889	19166

* **Calculated without taking into account of early expenditures of the Company on drilling and field construction ($28 mln.)**

** **By average rate of exchange of the dollar 32 rouble/$**