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THE WAYS OF TRANSFORMATION OF SALT PRODUCTION FROM THE SALINE LAKES OF APSHERON PENINSULA*

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The issues of salt production at salt lakes of Apsheron Peninsula in Azerbaijan are reviewed here. The paper objective is to examine the brine formation process and analyze the ways of transformation of salt extraction from the lakes of Apsheron Peninsula under ever increasing industrial development and urbanization. The research on ecological state of salt lakes at the peninsula have shown that the decades-long development of oil and gas and other industries had a dramatical impact on the natural properties of water resources in this area. Laboratory test revealed high concentrations of total hydrocarbons, phenols, toxic metals (Cd, Pb, Zn, Ni, Cu, V, Mo, etc.), surface-active suspended solids and other pollutants in water samples of salt lakes. The paper presents physical and chemical properties of Boyukshore Lake, which for many years was the republic's primary source of cooking salt. Based on comparative analysis of obtained properties with the maximum allowable concentrations and international standards the level of pollution of natural salt lakes of Apsheron has been assessed and the contribution of each anthropogenic source to the pollution of these water bodies has been determined. The paper presents quantitative and qualitative properties and pictures of the lakes depicting formation of saline deposits and volumes of salt produced at brine lakes of Apsheron. It has been established that decades-long negative impact on the environment led to disruption of ecological balance of the open waters in the region. Most saline lakes in the peninsula lost their natural qualities and became unsuitable for salt production.

***Key words*:** Apsheron Peninsula, salt lakes, brine, Boyukshore Lake, Masazir Lake, solt production.

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Introduction. Owing to its natural resources Apsheron Peninsula is one of the world famous regions, where for many centuries large amounts of hydrocarbons have been produced. It extends for over 2000 km^2 at the western coast of the Caspian Sea in the eastern part of the Republic of Azerbaijan. It is host to the republic's largest industrial cities – Baku and Sumgayit. The terrain with absolute elevations ranging from –27 to 350 m is dominated with flatlands, hills, ravines and valleys. The peninsula climate is that of moderately warm semi-deserts and dry steppes with dry summers. The average annual air temperature is 12-14 °C, in January it is +3 °C, and in July 25-27 °C. Total annual solar radiation is 130-135 kcal per cm^2, the precipitation is 200-300 mm per year and evaporation rate is about 1000 mm per year. Widespread in the region are gray and gray-brown soils with low humus content (1.0-1.5 %), while alkaline soils are predominant in drainless lowlands [6, 8, 9].

Ground water level is generally 2-10 m above the earth surface, by the degree of mineralization the waters are often brackish. The pressure waters flowing from deep layers have high mineralization (15-120 g/l) and partially feed the lakes.

There are almost no rivers at Apsheron, hydrographic network is represented by salt lakes, most of which dry out in summer. There are over 100 of such ephemeral drainless lakes, the total area of which varies from 0.001 to 12 sq.km, while quantity-wise small lakes with area of several hectares are predominant. The arid climate of the peninsula is not conducive to the formation of freshwater lakes here. Salt lakes play an important role as compared to other water bodies of the republic (Fig.1).

Ancient traveller and writers made mentions of cooking salt production at salt lakes of Apsheron [2]. In ancient times the population of villages located near the salt lakes in warm season collected deposited salt both for its own needs and for sale to other regions. During the Baku Khanate (from 17th century to the beginning of 19th century) all salt lakes belonged to the Baku khan, who leased those to the lessees. I.A.Sheyhzade noted [10] that with the accession of the Baku Khanate to

*In the Republic of Azerbaijan the name Apsheron was changed to Absheron.

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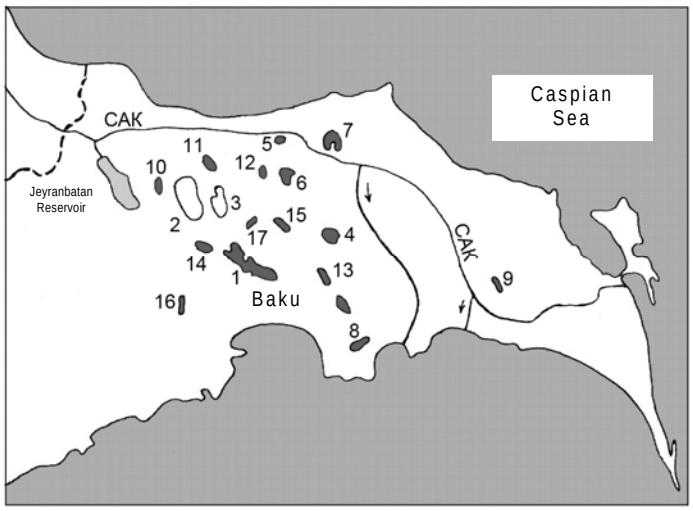

Fig.1. Map of Salt Lakes of Apsheron Peninsula

1, 4-17 – lakes used for salt production in the end of 19th century and beginning of 20th century, but consequently lost salt resources due to pollution (1 – Boyukshore, 4 – Ramana, 5 – Pirshagi, 6 – Mukhammedli, 7 – Kurdakhani, 8 – Zych, 9 – Gala, 10 – Sarayshor, 11 – Sianshor, 12 – Fatmai, 13 – Bulbulya, 14 – Binagadi, 15 – Zabrat, 16 – Hodzhagasan, 17 – Digah); 2, 3 – lakes presently used for salt production (2 – Masazir, 3 – Mirzaladi); CAK – Samur-Apsheron Channel

Russia the Baku solar salt lakes, which were used by the leaseholders, fell under state control and management thereof became the task of the Mines Department.

Important role in the development of Baku city was played by oil, salt and saffron, which were exported to the eastern countries. The available data shows that the second largest industry in Baku was salt production. In the end of 19th century and beginning of 20th century the cooking salt was produced in Baku at such salt lakes as Boyukshor, Zykh, Gala, Masazir, Kyurdakhany, Hodzhagasan and Jeyranbatan [13]. All production processes were manual and labour intensive. In average about 300 workers were engaged in salt production in Azerbaijan in the beginning of the last century. The salt was by sea exported from Baku to Russia, Iran and other countries. After setup of the Soviet government in 1921 the entire salt industry, including salt lakes of Apsheron, was put under control of a single department, namely the Azerbaijan Salt Department, which later on was renamed into Azsoltrest, Azsol and Baksol.

Research Materials and Methods. For assessment of ecological state of the Apsheron solar salt lakes their physical and chemical properties have been examined. Water samples for analysis were taken at different locations within the water bodies under research. The water samples were analyzed for: pH, electric conductivity, dissolved oxygen, chlorides (Cl^-), nitrates (NO_3^-), ammonium (NH_4^-), suspended solids, total hydrocarbons (THC), phenols, surfactants (SA), heavy metals, biological oxygen demand (BOD) and chemical oxygen demand (COD). Laboratory tests were carried out using the generally recognized methods [7]. Hydrogen index pH and electric conductivity were measured using appropriate devices. The concentration of dissolved oxygen was determined by traditional Winkler's iodometric method. The concentration of phenols, nitrates, ammonium and surfactants was determined photometrically and of chlorides by titration. The total hydrocarbon content was determined by gas chromatography (GC), the content of heavy metals by optical emission spectrometry with inductively coupled plasma (ICP-OES). Biological oxygen demand was determined by microorganism incubating in water samples in an oxygen flask without air for 5 days and then measuring oxygen absorbed. Chemical oxygen demand was determined by the colorimetric method using potassium dichromate. Total suspended solids was determined by gravimetric method. Test results were compared with international standards established for water systems and maximum allowable concentrations (MAC) adopted by the Cabinet of Ministers of Azerbaijan. The chemical composition and degree of mineralization of lake waters were assessed based on hydrochemical classification proposed by O.A.Alekin [1, 12, 17].

Results and Discussion. Since the end of the 19th century the Apsheron Peninsula has undergone intensive industrialization and urbanization. Extensive anthropogenic interference (a huge amount of industrial and household emissions) has led to changes in the peninsula ecosystem.

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Oil fields and related industries occupy about 30 % of the peninsula's area. As revealed by the conducted studies there are high concentrations of pollutants in the soil. They get accumulated in the soil and then migrate into lakes, water reservoirs, surface and underground waters throughout the peninsula. At present there are about 200 water reservoirs on the peninsula, both natural and man-made, most of which are polluted with oil products.

All natural lakes in one way or another suffer from human intervention. Some lakes are mainly polluted with oil industry effluents, while others - with household wastewaters, and many lakes get polluted with multicomponent discharge waters (Table 1).

According to hydrochemical classification of O.A.Alekin [1] the lakes under research in their natural state belonged to the sodium group of chloride or sulfate class. Water mineralization ranged from 50 to 200 g/l. Due to pollution of the catchment area and the aqueous environment of lakes with oil products, surfactants, pesticides, phenols, household and industrial technogenic and toxic wastewaters the natural equilibrium in a system "water catchment -aqueous environment – bottom sediments" was disturbed. Today the dominating factor predetermining the chemical composition of lake waters is not the natural processes, but the volume, material composition and concentration of anthropogenic wastes discharged into the basins [11, 14].

Table 1

Ecological state of salt lakes of Apsheron Peninsula

Number in Fig. 1	Name	Absolute elevation, m	Water surface area, km^2		Brine mineralization in the beginning of summer, g/l		Level of pollution*	Major sources of pollution**
			Natural state	Disturbed state	Natural state	Disturbed state		
1	Boyukshore	6	11.5	13.0	> 300	10-30	H	1, 2, 3, 4, 6
2	Masazir	0	8.2	9.1	> 300	300	L	5, 6
3	Mirzaladi	5	3.6	3.9	> 300	~300	L	5, 6
4	Ramana	–	0.4	0.5	~250	30	H	1, 3, 6
5	Pirshagi	–5	0.3	0.4	~250	200	M	5, 6
6	Mukhammedli	10	0.8	1.05	~200	40-100	M	4, 5, 6, 2, 3
7	Kyurdakhany	4	1.9	2.4	~300	80-200	M	3, 4, 5, 6, 1
8	Zykh	–25	0.7	1.1	~300	50-200	H	1.3
9	Gala	0	0.7	0.9	~250	~100	H	1, 6
10	Sarayshor	41	0.12	0.12	~250	~250	M	5, 6
11	Sianshor	21	0.3	0.46	~200	80	H	1, 6
12	Fatmai	–	0.4	0.4	~300	~150-250	L	4, 5, 6
13	Bulbulya	4	0.7	1.2	~200	2-6	M	6, 2, 3, 4
14	Binagadi	14	0.7	1.16	~250	2-4	H	1, 4, 6
15	Zabrat	27	0.2	0.4	~200	30-80	H	1, 2, 3, 4, 6
16	Hodzhagasan	11	0.9	1.8	~150	2-4	H	1, 3, 4, 5, 6
17	Digyakh	22	0.3	0.4	~150	~120	M	4, 5, 6
	Jeyranbatan	29	The valleys of these lakes were turned into the fresh water reservoir Jeyranbatan having total area of 13.9 sq.km. and water volume 186 mln.m^3.					
	Atbatan	–						

*Degree of pollution: H – High, M – Moderate, L – Low.
**Sources of pollution: 1 – oil plant effluents, 2 – construction wastes, 3 – wastes of other industries, 4 – household wastes, 5 – wastewater after field watering, 6 – sewage.

Though there are about 100 natural lakes on Apsheron Peninsula, not all of them have salt, i.e. sodium chloride (NaCl), sediments. The annual precipitation is not high and concentration of salt in the soils of lake catchment area does not exceed 2 %, i.e. dissolution and transfer of large amounts of salt from the catchment area to the lake is impossible.

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Table 2

Physical and chemical properties of water in Boyukshore Lake

Parameter	UOM	MAC	Parameter value
pH		6.5-8.5	9.3
Specific conductivity	Sm/m	–	3.1
Dissolved O_2	mg/l	≤ 4.0	3.9
Temperature	°C	–	22
NO_2^-	mg/l	3.3	0.19
NO_3^-	mg/l	45	0.66
NH_4^-	mg/l	0.5	0.56
Chlorides	mg/l	350	1834
BOD	mg/l	3.0	156
COD	mg/l	10	70.6
Surfactants	mg/l	0.1	0.95
THC	mg/l	0.05	2.6
Phenols	mg/l	0.001	0.005
Suspended solids	mg/l	0.25	30
Zn	mg/l	0.5	35.06
Cu	mg/l	0.01	1.72
Ni	mg/l	0.1	6.07
Pb	mg/l	0.03	0.56
Cd	mg/l	0.001	0.044

Research on the geological, hydrological and hydrochemical conditions [3-5] revealed that for regular formation of brine the lake shall receive highly mineralized pressure waters from the productive strata which emerge deep in the earth interior and rise upwards to the lake basin. Water evaporation from the lake surface gets more intense in the warm season, which accelerates lake mineralization processes and lake water gradually turns into brine. Salt sedimentation intensifies with the growing concentration of salt in the brine.

Thus it may be affirmed that the major salt feed in the lakes where salt sedimentation occurs are the underground waters. Though it shall be noted that over the last century the flow rate of highly mineralized underground waters has reduced due to the drop in pressure of edgewater in productive stratum related to intensive recovery of oil deposits.

Previously most Apsheron salt was collected at Boyukshor Lake. The basin of the lake is confined to the southern wing of anticline arc surrounding the Baku synclinal trough from the north. Boyukshore Lake is located in the center of Apsheron Peninsula at the absolute elevation of 12 m. It is the largest and most contaminated lake of the peninsula. The water volume is about 45 mln. m^3, surface area is 13 km^2, maximum depth is 3.5 m. As a drainless body of water Boyukshor Lake is fed with underground and surface waters from the catchment area. Starting from the first half of the last century huge amounts of oil industry effluents were discharged into this lake. According to the Ministry of Ecology and Natural Resources of Azerbaijan the total average daily volume of wastes discharged from 49 industrial and household facilities to Boyukshor Lake comprises about 18 ths.m^3 [15]. As studies show decades-long pollution with harmful substances had a dramatical impact on physical, chemical and biological properties of the lake (Table 2).

The earlier studies confirmed [3], that NaCl reserves in the brine of Boyukshor Lake comprised 841 ths. tons. The amount of salt contained in the lake in the form of salt crust comprises about 381198 tons, of which only half is suitable for production – 190 ths. tons. Permanent annual volume of salt fed into the lake according to the estimates is not exceeding 9 tons. According to the authors in July 1934 the amount of NaCl in the brine was 99.2 %, the average thickness of the salt crust was 4.8 cm, and the maximum thickness was 12.5 cm.

Industrial salt production was started in 1930. Due to growing demand and a need to improve the salt quality in 1930 on the western side of the Boyukshor Lake the salt production facility was built, which included 44 salt ponds with total area of 37.9 ga and production capacity of 30 ths. tons of salt per year. Total reserves of cooking salt in the lake brine in 130 comprised 775 ths. tons, and by 1957 reduced to 360 ths. tons.

In the first years of its operation the Baksol saltery outperformed the projected capacity, hitting its maximum 38700 tons in 1935. Further due to intensive development of oil production and expansion of nearby settlements the inflow of wastewater and low mineralized drill water increased. As a result the lake brine level gradually increased, while mineralization decreased, leading to decline in salt production.

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In a period from 1931 to 1944 Boyukshore Lake in average yielded 30 ths. tons of salt per year. In the years 1945-1950 the output dropped down to 16 ths. tons and over 1955-1956 further down to 8300 tons.

The lake exploration in 1950 revealed that in order to increase salt output of the existing salt ponds it would be useful to arrange a system of pretreatment ponds. But the lack of free space around the lake had thwarted these plans.

Since 1952 water from Boyukshore Lake has been used not only for feeding ponds of Baksol Company, but also for flooding the oil fields. A massive outflow of highly mineralized water from the lake and inflow of low-mineralized drill and waste water to the lake led to the rapid reduction of salt concentration in the water of the lake. In 1957 V.D.Bizin and F.A.Petrachkov [3] came to a conclusion that with NaCl concentration around 30 g/l the further salt extraction from Boyukshor Lake was not practicable. This lake lost its value as the feedstock base for cooking salt production at the evaporation ponds.

Over the next few years due to intensive development of hydrocarbons extraction at Boyukshore Lake and other lakes suffering from anthropogenic wastes the salt production was stopped. Among multiple solar salt basins of Apsheron the salt production potential is still preserved at Masazir Lake and a small Mirzaladi Lake to the east of Masazir (see Fig. 1). The basins of Masazir and Mirzaladi lakes are confined to synclinal structures made of loose sand-clay sediments of productive stratum.

The water area surface of Masazir Lake is about 10 km^2, its length is 4.7 km and the average width is 2.1 km. The lake depth varies widely from 0.1 m to 1.0 m. The water salinity reaches 330 g/l and NaCl concentration comprises 270 g/l. The salt exists in the lake in solid form as deposited layers and in the form of solution. Huge amount of bottom sediments is accumulated in the lake depression, thickness thereof is over 9.5 m. The salt layers are found within certain depth intervals at the bottom of Masazir Lake, such as layers 0.3 m thick at the depth of 4.80-5.10 m, 0.05 m thick at the depth of 5.75-5.80 m, 0.15 m thick at the depth of 6.45-6.60 m and 0.3 m thick at the depth of 7.30-7.60 m [17] (Fig.2).

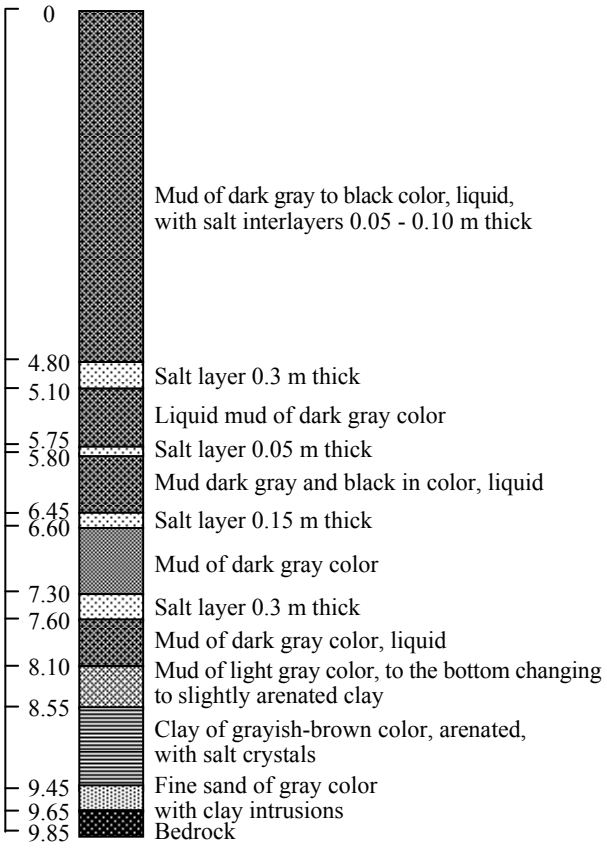

Fig.2. Profile of bottom sediments in the central part of Masazir Lake (based on materials compiled by Ya.V. Gavrilov).

As concerns mineralogic composition of bottom sediments (at depth of 0.2 m) of Masazir Lake, the pyroxenes (50 %) dominate among heavy fractions and the clay mineral fractions (92 %) – among the light fractions.

The water catchment area of drainless Mirzaladi Lake is about 12 km^2. The lake water surface area is 3.4 km^2, the length is 3.8 km,

Fig.3. Evaporation of salt extracted from Masazir Lake

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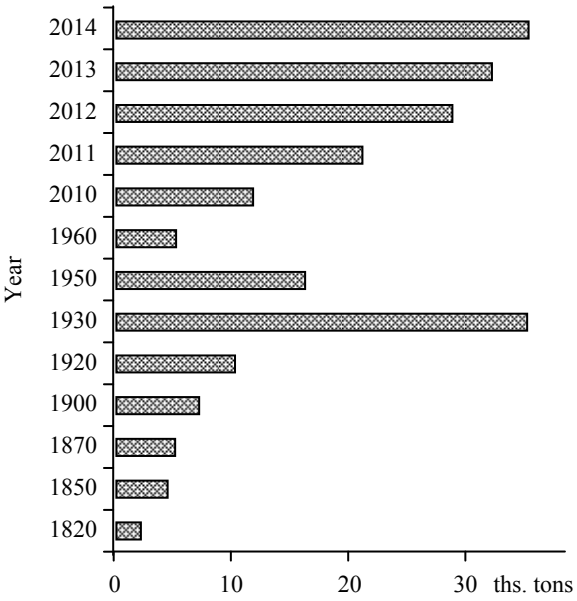

Fig.4. Dynamics of salt production at brine lakes on Apsheron Peninsula

the maximum widths is 1.7 km and the maximum depth is less than 1 m. The lake is fed with precipitation and underground highly mineralized waters. In the recent decades the lake also received household wastes from the nearby settlement. By chemical composition the lake water belongs to the chloride class, depending on annual rainfalls and seasons its mineralization varies from 50 to 300 g/l.

While being a major source of feedstock for salt production, the solar salt lakes have amazing natural qualities. As the water salinity is very high (300-350 mg/l), it's unfit for fish and many other species which usually inhabit the lakes. Often Dunaliella Salina microorganisms, which are microscopic single-celled moving algae, live in there. Their cells contain red pigment beta-carotene. The algae absorb the solar light and give out red pigment, dying the lake water in pink and red colors. Such lakes are usually called "the flamingo-color lakes". This phenomenon is also typical for Masazir and Mirzaladi lakes [13] (Fig. 3).

In 1924 during exploration of salt resources of Azerbaijan Ch. Ildyrym noted [5], that 249 ths. tons of salt may be extracted from Masazir Lake. In 1934 the geologist Ya.V. Gavrilov [4] based on a comprehensive hydrogeological survey of the basin of Masazir Lake came to a conclusion that the lake contains 381 ths. tons of salt. According to the present-day estimations* the lake has about 1.735 ths. tons of salt.

Pursuant to the Law On Compulsory Salt Iodization adopted by the Government of Azerbaijan in 2002, the import of non-iodized salt into the country was banned.

Since 2010 salt extraction from the solar salt lakes is under the control of the production association Azerduz. This is the first plant established in Azerbaijan for iodized salt refinement and production. The plant is equipped with modern machinery complying with the international standards. Initial daily production capacity of the plant was 100 tons. Today the daily output of the plant is 300 tons (Fig.4).

The plant is producing salt of two types: the refined cooking salt extracted from the lake water, and the salt under "Top Grade" trademark (in Russian "Vysshiy Sort") produced out of the salt layer. In addition to covering more than 50 % of the republic's internal need in cooking salt, the plant products are exported to Russia, Georgia and Kazakhstan*.

Conclusion. Based on the data presented above a conclusion can be made the salt lakes of Apsheron Peninsula in Azerbaijan since ancient time served as a feedstock base for cooking salt production. Analysis of the current state of Apsheron water bodies revealed that as a result of decades-long man intervention most salt lakes became unsuitable for salt production. Two underlying factors are: sharp increase in discharge of low mineralized (as compared to the lake brine) drill and household wastewater, which led to reduction in the level of lake water mineralization, and water and bottom sediments pollution with substances alien to limnogenesis. The research has shown that Masazir Lake and Mirzaladi Lake located near Masazir have conditions favourable for cooking salt production and processing. As unique natural water bodies, these lakes contain considerable reserves which can be used for salt production for many years.

* www.azerzun.com/az/content/duz

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