THE HYDRO-CHEMICAL CHANGES OF LAKE SEVAN WATER AFTER THE ARTIFICIAL LOWERING OF THE WATER LEVEL

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Abstract. The paper is aimed to show the influence that the dynamics of artificial lowering of a lake water level has on the hydro-chemical regime and the lake itself, on the example of Lake Sevan. Lake Sevan is one of the world's largest high-altitude fresh-water lakes. Studies of chemical composition of its water were launched at the end of the 19th century, and the first salt balance was determined in the 1930s. According to routine observations, one liter of the lake's water contains about 0.7 g salts. Almost all the ion concentrations have been changed by about 5–10% as a result of the lake level drop. There have also been changes in the general mineralization of the lake that are related to the drop of the lake level and the magnitude of its flow. In 1928–1930, well before the artificial change in lake level, total mineralization was 718,4 mg/l, while today it is 673 mg/l (1999–2002). The decrease of total general mineralization of the lake water is strongly related to the massive outflow of salty water, removing the salts, which had been accumulating in the lake for ages. In conclusion, it must be noted that the drop of the lake level, and the economic development in the basin brought about the change in the hydro-chemical regime of the lake.

Keywords: Lake Sevan, anthropogenic changes, hydro-chemical composition and regime, mineralization, eutrophication.

1. Introduction

Numerous rivers, lakes and, in general, water bodies have undergone considerable changes under the impact of the economic activity of man. As a result, hydrological, biological conditions as well as the morphometrical elements of these bodies have been destroyed. Lake Sevan and its basin may serve as a classical example in this respect (Fig. 1.1).

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Lake Sevan is one of the high-altitude freshwater lakes in the world and is the largest lake in Caucasus. Lake Sevan is regarded to be a large reservoir of fresh water not only for Armenia, but also for the countries of the region.

Originally, before 1930, the surface of Lake Sevan was on the height of 1916 m above sea level. The surface of the drainage area of the lake before its artificial drop (1930s) was 3475 km^2, that is larger than the surface of the lake by 2.5 times (1416 km^2), and the volume of lake water was 58 billion m^3 (Table 1.1).

Fig. 1.1. The river network of Lake Sevan.

Table 1.1. Some hydrometric indices of Lake Sevan.

Indices	Unit of measurement	Before the drop of the level	Present-day condition
Drop of lake level	m	0.0	19.43
Height above sea level	m	1915.89	1896.46
Watershed surface	km^2	3475	3649
Lake surface	km^2	1416	1242
Mean depth	m	41.3	25.9
Maximum depth	m	98.7	79.4
Water amount	km^3	58.5	32.8

The anthropogenic changes in the level of Lake Sevan took place during the last 70 years after the decision to deepen the riverbed of the Hrazdan river - the only river flowing out of the lake, with the aim of using the lake water for irrigation and energy generation.

The aim of the research was to explore the influence of the dynamics of the artificial lowering of the lake's level on the hydro-chemical composition and regime of the lake (in the last 70 years), with the case of Lake Sevan.

2. Results and discussion

In the world limnology, there was no other case when a lake level was artificially lowered for 18 m within 3–4 decades (1930–1970), and by another 2 m in the last decade (1990–2000) (Figs. 2.1 and 2.2).

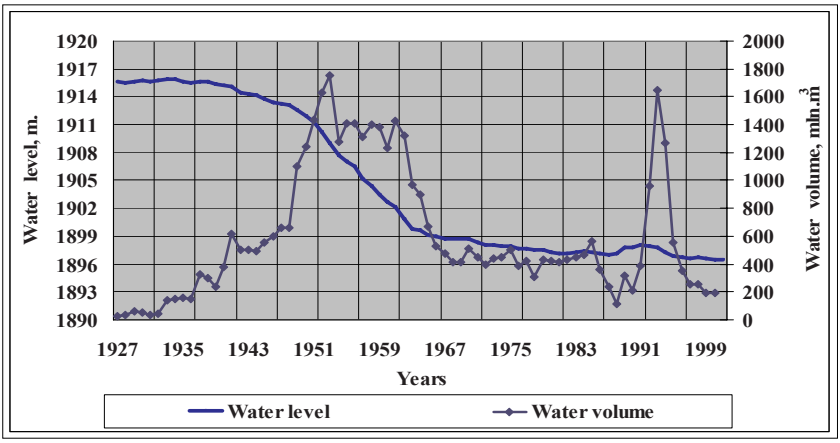

Fig. 2.1. The graph of perennial fluctuation of Lake Sevan level: annual total water outflow volume and average lake level.

In this respect, Lake Sevan is the only lake, which is considered to be a large natural laboratory, where one can observe all those processes connected with the decrease of erosion basis of flowing into the lake rivers, and which cannot be studied under laboratory conditions. Among these processes, the hydrological, thermal, hydro-chemical and carbon regime of the lake, as well as biological conditions, which have served as a rich material for scientific researches, are rather important.

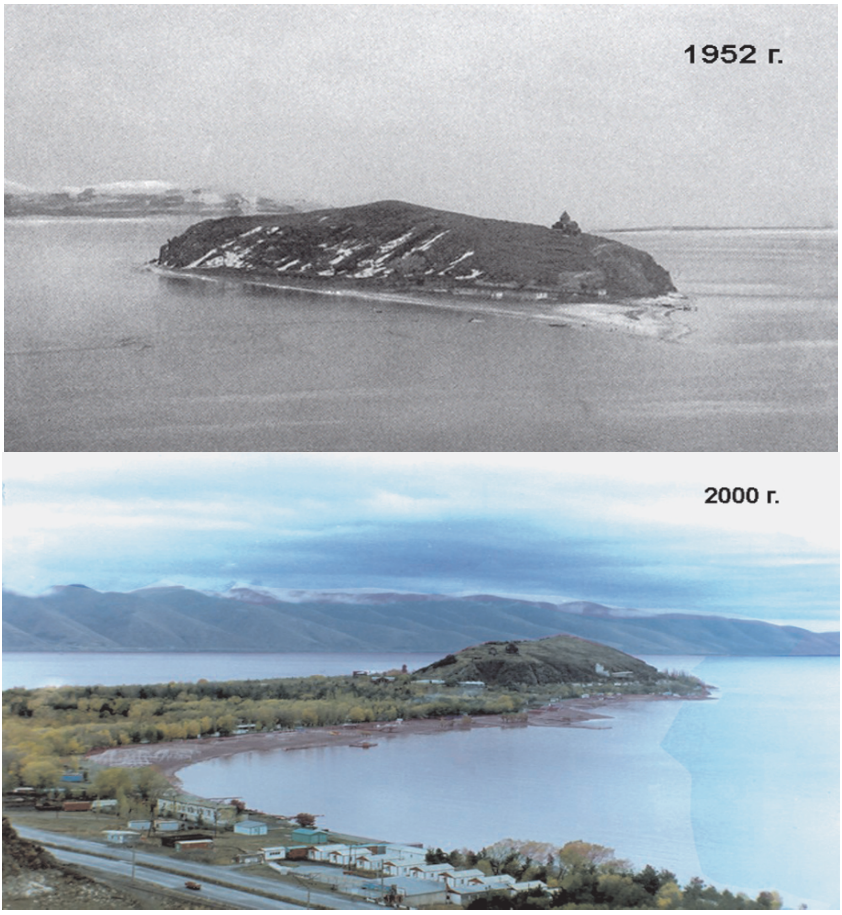

Fig. 2.2. As a result of the decrease of the lake's water level, the island became a peninsula.

The decrease of erosion basis caused the activation of channel processes of the rivers flowing into the lake (Fig. 2.3). It brought about the violation of the balanced profiles of river valleys, formed within thousands of years. The active down-cutting erosion destroyed the foundations of bridges and caused their collapse.

Table 2.1 and Fig. 2.4 allow to figure out the chemical composition of Lake Sevan water in natural state, i.e., before its artificial lowering (1930), and the changes that have taken place since then.

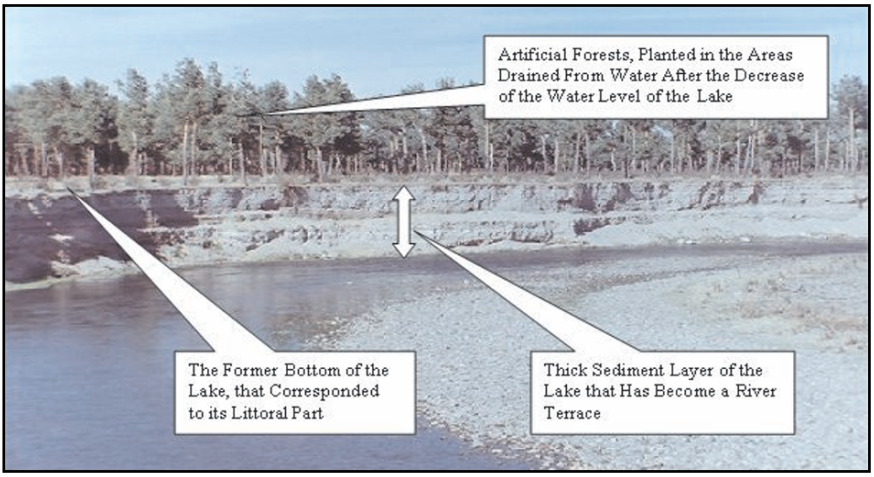

Fig. 2.3. The riverbed of the Argichi River, which has been deepened as a result of the drop of Lake Sevan level.

Table 2.1. The mineralization of Lake Sevan water and its ionic composition in different years.[a] ∑U = Total Mineralization (mg/l).

Ionic composition	Before the drop of the level (1928–1930)	Present-day condition
Ph	9.2	8.6
Ca	33.9	20.6
Mg	55.9	55.4
Na+K	98.7	92.8
HCO_3	414.7	373.0
CO_3	36.0	21.2
Cl	62.3	68.0
SO_4	16.9	29.2
∑U[a]	718.4	660.2

Lake Sevan is one of the world's largest high-altitude fresh-water lakes. Studies of the chemical composition of its water were launched at the end of 19th century, and the first salt balance was determined in 1930s [1]. According to routine observations, one liter of the lake's water contains about 0.7 g salt in ionic form. The hydro-carbonate ion (HCO_3) and chlorine (Cl), at 414.7 mg/l and 62.3 mg/l, respectively, dominate in the ionic composition among non-metals. Among cations, magnesium (Mg) with 55.9 mg/l, and sodium plus potassium (Na + K), with 98.7 mg/l, dominate.

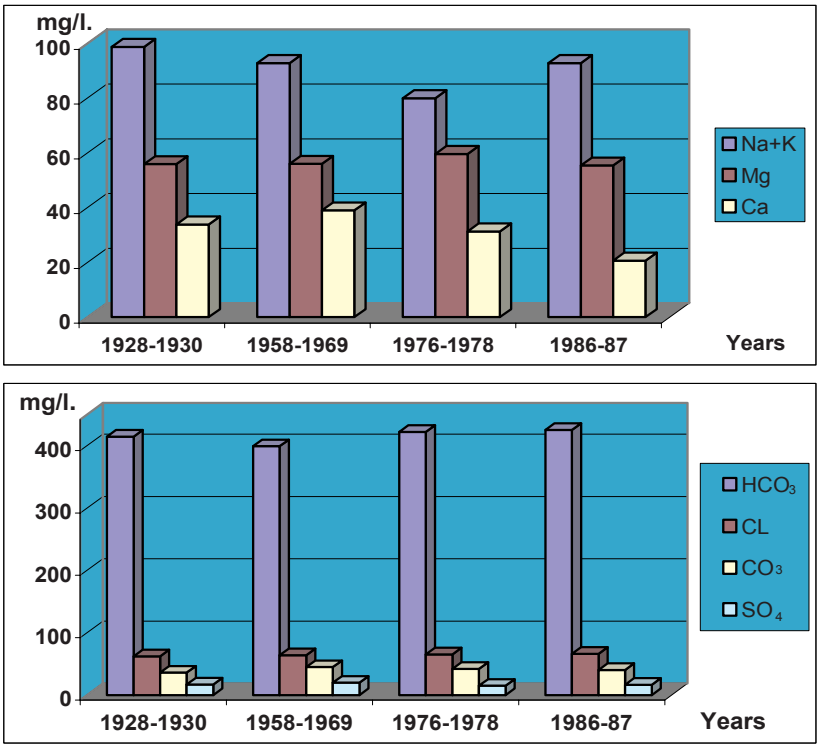

Fig. 2.4. The change of the main ions in the chemical composition of the lake.

Almost all the ion concentrations have been changed by about 5–10% as a result of the drop of the lake level. The calcium concentration has been changed the most. At the end of 19th century, calcium concentration was 38 mg/l, while a century later it was only 21 mg/l [2]. This phenomenon has not yet been closely studied, but some opinions link the lack of calcium in Sevan water to the intensification of plankton photosynthesis. The concentration decrease started in 1978. At the same time, the lake productivity dropped and the growth of blue-green algae abruptly decreased. These changes were observed after an increase of turbidity. The current low level of calcium may lead to another change. The lake water is a rich solution containing Ca^{2+} and CO_3^{2-} which form a poorly soluble $CaCO_3$ carbonate, which settles on the lake bottom.

At present, the ion concentrations in the water are as follows:

$$HCO_3 > Na+K > Cl > Mg > SO_4 > CO_3 > Ca$$

To start with $HCO_3 > Mg + Ca$ indicates that according to Aliokhin's classification, Lake Sevan belongs to the magnesium group of the hydro-carbonate lake category.

There have also been changes in the general mineralization of the lake that are related to the drop of the level and the magnitude of its flow (Fig. 2.5).

In 1928–1930, well before the artificial change in lake level, the total mineralization ∑U was 718.4 mg/l. Even during the rapid changes of 1958–1969 it changed little, being 716 mg/l. After 1980 the mineralization sharply decreased, becoming 706.9 mg/l as low as 660 mg/l in 1986–1987 and 673 mg/l at present (1999–2002).

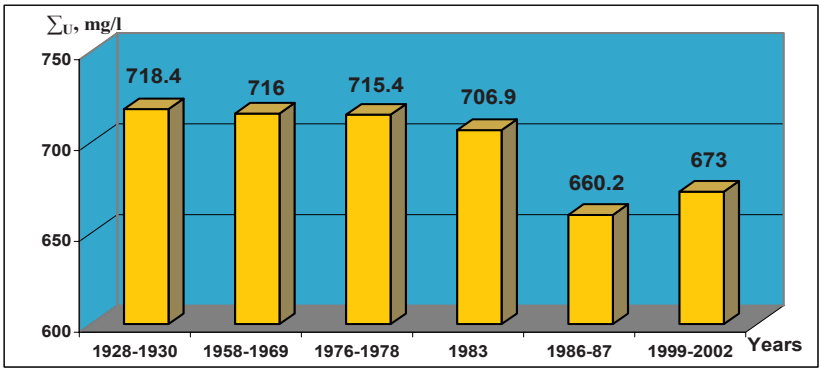

Fig. 2.5. The change of the total mineralization (∑U, mg/l).

The decrease of the total general mineralization of the lake water is strongly related to the massive outflow of salty water, removing the salts, which had been accumulating in the lake for ages.

For comparison, the total mean mineralization of the river waters flowing into the lake is 160–180 mg/l [3].

3. Conclusions

In conclusion, it must be noted that the drop of the lake level and the economic development in the basin brought about the change in the hydro-chemical regime of the lake. The latter caused the disruption of the thermal and hydro-chemical regimes of the lake. The quality of the water deteriorated, water turbidity increased. The inner circulation of the water constituents as well as the circulation of the biological substances altered, as well.

In the next 20–30 years it is envisaged to increase the level of the lake by only 4-6 m, because if the level rises more than that, the recent coastal constructions (roads, railway, resort houses, and others) as well as tree-shrub vegetation (they were artificially planted and grown after the drop of water level) will go under water. However, the latter one is reality today. In the recent 5 years, the water level of the lake has increased by more than two meters, which is the effect of the growth of surface flow and decrease of outflow from the lake.

As a result, a new issue emerged; namely the coastal green zone is under water. Considerable water lever increase took place so fast and unexpectedly, that there was no time to clear the coastal line from its green cover, thus, endangering the lake with eutrophication.

It is hard to predict the future developments of these processes. However, the issue of Lake Sevan is not entirely settled, the ecosystem of the lake is damaged, undergoing the process of eutrophication. The flora and fauna of the water and coast underwent serious and irreversible changes.

These are the old and new issues of Lake Sevan and its basin.

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