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WATER QUALITY OF LAKE KATLABUKH

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Abstract. The soil and thermal resources of the Odessa region allow growing a variety of agricultural crops with a yield much higher than currently obtained. But this is possible only when using irrigation. The southwestern part of the region has such a powerful source of water as the Danube River, from which irrigation is carried out and the lakes Cahul, Yalpug, Katlabukh, China and a number of reservoirs are filled. For a number of reasons, after 2000 the actual amount of irrigated land has decreased significantly. Along with this, the quality of water in reservoirs changes, and sometimes they disappear from the map. At the state level, various programs are being adopted to restore irrigation in the southern regions of Ukraine without understanding the presence and hydrochemical composition of the waters of reservoirs.

To do this, it is necessary to conduct a detailed analysis of the presence of water bodies and assess their chemical composition. This work is devoted to one of the sources of water supply for the national economy, namely Lake Katlabukh.

Lake Katlabukh is used as the main source of irrigation for three state systems - Suvorivskaya, Izmailskaya and Kislytskaya (formerly Kirovskaya) irrigation systems (IS) and small irrigation areas (SIA) on an area of 16.671 hectares. In addition, the Loschinivske, Kaminske, Banivske and Muravlivske reservoirs were additionally filled with lake waters to irrigate 22063 hectares within the limits of the Loschinivske, Tashbunarske, Muravlivske and Banivske IS and the SIA adjacent to them.

The aim of the work is to analyze the hydrochemical state and assess the quality of water according to agronomic criteria over a thirty-year period of one of the lakes, the waters of which have been and continue to be used for irrigation.

To solve this problem, materials of hydrochemical observations were collected and processed. The main indicators of anionic and cationic composition, mineralization index and pH are summarized and averaged for every five years from 1991 to 2020. Separately, data for 2021 is given. To assess the quality of water according to agronomic criteria, all indicators were calculated according to the latest methodology. The main reasons for the deterioration of water quality have been identified.

Keywords: water quality, agronomic indicators, irrigation water, mineralization, reservoir.

Introduction. The hydrochemical and nutritional regime, physical and physicochemical properties, and, accordingly, the fertility of the soil are largely determined by the quality of irrigation water. Water with high mineralization leads to salinization, and water with low mineralization leads to excessive salinization and leaching of nutrients from the soil. Water with an unfavorable ratio of monovalent and divalent cations causes salinization, alkalization and soil degradation.

Climatic features of the region are that the limited factor that limits the amount of yield is the lack of moisture. It was possible to increase the yield only by supplying water to the fields with a certain agricultural technology. Irrigation in this territory was carried out in a small amount in pre-war times, it began to develop in 1947, when the government of the Ukrainian SSR made a decision on watering and irrigation of the Izmail region [1]. But intensive construction began in 1966.

Irrigated areas in 1966 amounted to 31.5 thousand ha, in 1991 – about 240 thousand hectares [2]. At the beginning of 2022 this figure has hardly changed.

From 1991 to the present, the land that is actually irrigated has decreased significantly and the quality of water for irrigation has changed. Several main reasons contributed to this: *land reclamation* – many new landowners appeared, who are economically unable to irrigate their small plots of land and maintain meliorative systems in a satisfactory condition; *introduction of paid water use* – led to a decrease in water use by consumers, partial or complete cessation of preventive discharges and flushing of reservoirs; *various "optimizations"* led to a decrease in the personnel potential of water management departments and uncertainty regarding the further development of irrigation. Weather and climatic conditions together with the hydrological regime of the Danube River, the main supplier of water for reservoirs used for irrigation, also play an important role.

Analysis of recent research and publications. Mechanisms of interaction between irrigation water, soil solutions and the solid part of soils are very complex and diverse. This explains the fact that several methods were used to assess the quality of water during the period of the research given in this paper [3-5].

Until 1995 criteria proposed by M.F. Budanov, O.M. Mozheyko were used to assess water quality. and Vorotnik G.H. The assessment was carried out by determining the mineralization of water. From the point of view of the danger of salinization according to Budanov M.F. water is suitable for all types of soil, if the total mineralization does not exceed 1 g/dm^3. With a mineralization of 1-3 g/dm^3, water can be used for irrigation if the fraction of dividing the sum of concentrations of all mineral substances in mg-eq/dm^3 by the sum of calcium and magnesium concentrations does not exceed 4 for medium and heavy loamy soils, 5 for loamy soils and 6 for sandy and sandy soils.

As an indicator that evaluates the possibility of salinization of soils during irrigation, various authors used mathematically expressed ratios between monovalent and divalent cations in irrigation water in different ways. Mozheyko O.M. and Vorotnik G.H. for these purposes, the value of the ratio of the amount of Na^++K^+ to the sum of all cations in mg-eq/dm^3 was used. At the same time, if the ratio is less than 0.65, then the waters were considered safe in terms of salinization of the soil: 0.66-0.75 – dangerous, and more than 0.75 – very dangerous. According to Budanov M.F. water is unsuitable for irrigation if the ratio of Na^+ to Ca^{2+} is greater than 1 or the ratio of Na^+ to the sum of Ca^{2+} and Mg^{2+} is greater than 0.7.

In order to change this approach to the assessment of irrigated waters by the order of the State Standard of Ukraine N^o 194 dated 07.29.1994 a new standard was introduced, which was developed under the leadership of S.A. Balyuk [4]. According to agronomic indicators, water quality was evaluated according to five indicators: the danger of secondary salinization, salting and alkalizing of soils, toxic effects on plants, and thermodynamic indicators. Such an indicator as water mineralization in this standard is not taken into account at all.

In 2016, SSU 2730-94 was replaced by the order of SE "UkrSRSC" dated June 22, 2015 according to N^o 61, a new standard for assessing the quality of irrigation water according to agronomic criteria was introduced, which is used nowadays [5]. The assessment is also carried out according to the main five indicators. It differs from the previous one mainly in the determination of the amount of toxic salts in chlorine equivalents, the assessment of the danger of salinization, and numerical gradations in the assessment of water quality by all five indicators.

Lake Katlabukh was and is used as the main source of irrigation for three state systems – Suvorivska, Izmailska and Kislytska (formerly Kirovska) irrigation systems (IS) and small irrigation areas (SIA) on an area of 16.671 hectares. In addition, the Loschinivske, Kaminske, Banivske and Muravlivske reservoirs were additionally filled with lake waters to irrigate 22.063 hectares within the limits of the Loschinivske, Tashbunarske, Muravlivske and Banivske IS and the SIA adjacent to them.

The analysis of the existing materials shows the practical absence of thorough scientific publications by specialists on the quality of water in the Danube reservoirs, and in particular in Lake Katlabukh and reservoirs that have been filled with its waters since 1991. Individual publications cover only certain periods [6-11] or generalized global issues [12].

The goal of the work. The main increase in water needs in the near future may be associated, first of all, with the restoration and development of irrigation not only in Odesa, but also in other southern regions, which, in particular, is provided for by the corresponding concept and conceptual approaches, which are the basis of the strategy for the restoration of work and development of irrigation systems in Ukraine [13]. The concept envisages increasing the irrigated area in the Odesa region by 100,000 hectares. In addition, according to the idea of the authors of the report on scientific research work, it is possible to improve the water supply of other southern regions of Ukraine at the expense of water from the Danube River. But the implementation of the principles specified in [12, 13] is impossible without an analysis of the dynamics of the hydrochemical state, suitability and prospects for use on certain significant water bodies in the southwestern part of Odesa. Therefore, the *subject of the study* was Lake Katlabukh, as one of the main water bodies of irrigation and on which the condition of four more reservoirs, mainly in the Izmail district, depends.

Materials and research methodology. Lake Katlabukh is filled in the interfluent period with the Danube River by the main pumping station (MPS), with a supply volume of 11.1 m^3/s, and during floods – by gravity through the existing "Zhelyavsky" channel, at the head of which there is a two-way regulator lock. Water withdrawal from the reservoir to the irrigation arrays is carried out by four pumping stations: at the Suvorivska IS – PS-1 and PS-2; to the Izmailsk IS – MPS and to the Kyslytsk IS – MPS. In order to supply water to the irrigation network, pumping stations (PSS) were built. In order to connect the emergency water supply with the PSS water intake, they have regulating tanks-pools and main channels. Pools carry out daily regulation, connecting the uneven stepped supply of water into a closed grid. Water was supplied to the Loschinivske, Kaminske, and Banivske reservoirs through the pipeline system from PS-2 of the Suvorivska IS and MPS of the Izmailsk IS; to the Muravliv reservoir from PS-1 Suvorivska IS.

Until 1995-2000, irrigation was carried out by sprinkler machine (SM) "Volzhanka", two-console sprinkler unit – 100, partly by SM "Fregat". After 2000 in the structure of irrigation, the share of these aggregates was significantly reduced and drip irrigation appeared.

To analyze the water quality in the reservoirs, the results of chemical analyzes were collected and analyzed, which were taken directly at the PS and MPS during 1991-2021 and were carried out by the laboratory of the Odesa Hydrogeological and Reclamation Expedition (1991-2017) and the water monitoring laboratory of the Southern Region of the Separate Subdivision "Black Sea Center for Water Resources and Soils" (2018-2021). For ease of understanding, the obtained data were averaged for every five years, namely 1991-1995; 1996-2000; 2001-2005; 2006-2010; 2011-2015; 2016-2020 Data for 2021 are given separately.

To assess water quality according to agronomic criteria, SSU-2730-2015 "Quality of natural water for irrigation" was used. Agronomic criteria" [5].

Regulation of the quality of irrigation water according to agronomic criteria determines the quality of water for irrigation by its influence on:

1) soils, in order to preserve and increase fertility, as well as prevent the processes of salinization, salting, lithification and violation of the biological regime;

2) ensuring the planned yield of agricultural products, productivity and intensity of development;

3) the necessary quality of agricultural products, their completeness and good quality.

Standardization of irrigation water quality indicators according to agronomic criteria was carried out taking into account the composition and properties of soils in conditions when the level of groundwater does not exceed the critical level under the recommended irrigation regimes.

Agronomic criteria for assessing the quality of irrigation water were evaluated according to the following indicators: danger of irrigation soil salinization; the danger of soil calcification; danger of toxic effects of irrigation water on plants; the danger of salinization of the soil, the value of pH and water temperature.

Assessment of the quality of irrigation water according to the danger of irrigation salinization of soils was carried out on the basis of the indicator of the total concentration of toxic ions (in chlorine equivalents), taking into account the group of soils and their granulometric composition (SSU 7908). The risk of soil alkalinization was assessed taking into account the comprehensive assessment of most indicators – the value of the hydrogen index (pH), toxic alkalinity and alkalinity from normal carbonates (SSU ISO 10390, SSU 7845, SSU 7943) [5]. Assessment of the quality of irrigation water according to the danger of its toxic effect on plants was determined by the hydrogen indicator, the content of alkalinity from normal carbonates, the content of chlorine and the sum of toxic salts in chlorine equivalents. The danger of salting of soils was determined by the ratio (in percent) of the sum of alkaline cations of sodium and potassium to the sum of all cations, taking into account the main types of irrigation soils, their anti-saline buffering capacity and granulometric composition of soils, the amount of excess of magnesium over calcium in irrigation water, and the class of water according to danger calcification of soils.

When assessing the quality of irrigation water, three classes of its suitability are distinguished: Class I – "*Suitable*", Class II – "*Limited suitability*" and "*Unsuitable*" (Class III).

Research results. For the assessment of water quality according to agronomic criteria, during the period given in the work, various methods were used, therefore, based on previously obtained data, we assessed water quality according to the last one [5]. Chemical composition of water and assessment of its quality according to agronomic criteria during 1991-2021 shown in Table 1. In total, more than 270 water samples were analyzed.

Table – 1 Assessment of the quality of irrigation water according to agronomic criteria

Date of selection	Assessment of the quality of irrigation water by hazard					
	Secondary salinization		Alkalinity of soils			
	Concentration of toxic ions, mg-eq dm^3	Water class	pH	CO_3 mg-eq dm^3	HCO_3 - Ca mg-eq dm^3	Water class
1991-1995	10.49	I	8.26	0.44	1.66	II
1996-2000	12.97	I	8.4	0.16	2.36	II
2001-2005	17.93	I	8.34	0.50	2,7	II
2006-2010	19.06	II	8.63	0.74	6.06	III
2011-2015	17.41	I	7.98	0.37	2.85	II
2016-2020	21.77	II	8.06	0.27	6.06	II
2021	16.76	I	8.32	0.47	3.17	II

Date of selection	Assessment of the quality of irrigation water by hazard							
	Toxic effect on plants					Isolation of soils		
	pH	CO_3 mg-eq dm^3	CL mg-eq dm^3	Concentration of toxic ions mg-eq dm^3	Water class	Class of water according to the danger of soil alkalization	The ratio of sodium and potassium cations to the sum of all cations %	Water class
1991-1995	8.26	0.44	5.28	10.49	II	II	58.92	III
1996-2000	8.4	0.16	7.91	12.97	II	II	67.41	III
2001-2005	8.34	0.5	10.56	17.93	II	II	75.12	III
2006-2010	8.63	0.74	9.86	19.06	II	III	76.43	III
2011-2015	7.98	0.37	10.56	17.41	II	II	62.31	III
2016-2020	8.06	0.27	13.56	21.77	II	II	73.98	III
2021	8.32	0.47	9.73	16.76	II	II	57.04	III

In Lake *Katlabukh*, the water is chloride-sulfate, magnesium-sodium, less often sulfate-chloride, sodium-magnesium. The mineralization index varies on average from 1.09 to 2.29 g/dm^3, with the variability of the minimum and maximum indicators being 0.35-2.29 g/dm^3 and 1.98-4.30 g/dm^3, respectively. At the same time, there is a gradual increase in the average and maximum indicators in the dynamics. The vast majority of waters are slightly salty according to the mineralization index [14]. According to the hydrogen indicator, the water is mostly alkaline – 7.98-8.63, although in some samples acidic properties were recorded – 6.23-6.90. It is characterized by a significant natural content of sulfates (8.25-18.69 mg-eq/dm^3) and sodium ions (8.00-20.07 mg-eq/dm^3), to a lesser extent – chlorides (5.28-11.56 mg-eq/dm^3) and magnesium ions (6.16-12.89 mg-eq/dm^3), which significantly affects water quality according to agronomic criteria. Since the concentration of the above-mentioned components increases with the mineralization index. According to most of the studied agronomic indicators, the water quality belongs to the II class, i.e. to "limited suitability". According to the danger of salting of soils, as a result of the increased ratio of the amount of alkaline cations of sodium and potassium, taking into account the magnesium content, to the amount of cations – up to III class, that is – "unusable".

Conclusions. Until 1991 the average annual rainfall did not exceed 400 mm. After that, there is a gradual increase from 400 to 500 mm, and in some years more than 500 mm (Fig. 1). At the same time, the number of days with precipitation and their intensity are changing, more and more precipitation is torrential in nature (Fig. 2).

Long-term observations of the dynamics of water quality in Lake Katlabukh testify to a significant change in water quality, which was influenced and is influenced by several main factors, namely: *de-soldering of land, introduction of paid water use, various "optimizations" of the water industry, etc*. An important role is played by weather and *climatic conditions together with the hydrological regime of the Danube River*, the main supplier of water for reservoirs used for irrigation.

The above-mentioned reasons, in turn, contributed to the change in water quality in reservoirs, and in our case, in Lake Katlabukh. In the reservoir, there is a gradual increase in the mineralization index, the concentration of the main ions (SO_4^{2-}; Cl^-; Na^+; Mg^{2+}). Everything is certainly reflected in the suitability of water for irrigation according to agronomic criteria. Mostly. according to most agronomic indicators, water quality belongs to class II, i.e. to "limited suitability". "Unsuitable" (III class) only due to the danger of salinization of soils, due to the increased ratio of the amount of alkaline cations of sodium and potassium, taking into account the magnesium content, to the amount of cations.

Implementation of the "Irrigation Strategy..." [13] is impossible without state support and regulation. At the same time, support should not be declarative, but nominal, financial. Without this, not only will the quality of water in lakes, reservoirs, and ponds not improve, but they may disappear altogether, as many reservoirs have already disappeared. In the conditions of "regulation" of the reservoir, in our opinion, it is necessary to carry out a number of priority measures with the involvement of state support, namely, conducting a bathometric survey, clearing and deepening suitable channels, increasing the actual irrigated land, etc.

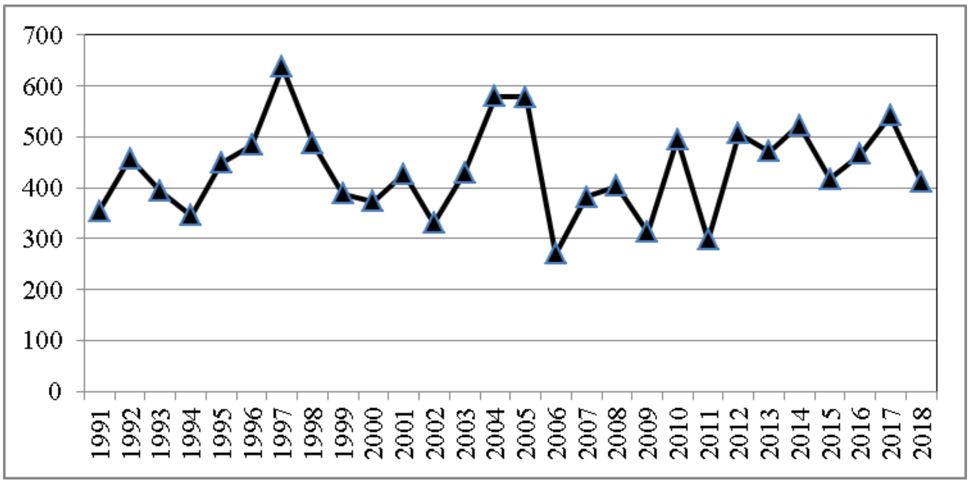

Fig. 1. Annual rainfall (mm) according to the data of the Tatarbunar balance measurement station

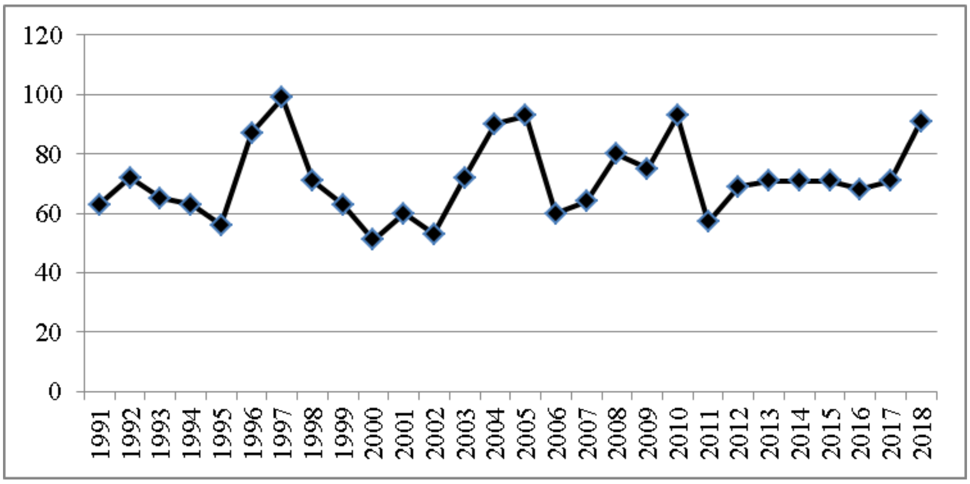

Fig. 2. Annual number of days with precipitation according to the Tatarbunar balance measurement station

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ЯКІСТЬ ВОДИ ОЗЕРА КАТЛАБУХ

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Анотація. Ґрунтові та теплові ресурси Одеської області дозволяють вирощувати різноманітні сільськогосподарські культури з врожайністю значно вище, аніж які отримають на даний час. Але це можливо тільки при використанні зрошення. Південно-західна частина області в своєму розпорядженні має таке потужне джерело води як річка Дунай з якої проводиться зрошення і заповнюються озера Кагул, Ялпуг, Катлабух, Китай і низки водосховищ. З ряду причин після 2000 року фактична кількість зрошуваних земель значно скоротилася. Разом з цим змінюється якість води в водоймах, а подекуди вони зникають з мапи. На державному рівні приймаються різноманітні програми по відновленню зрошення в південних областях України без розуміння наявності і гідрохімічного складу вод водойм. Для цього необхідно провести детальний аналіз наявності водойм і оцінити їх хімічний склад. Дана робота присвячена одному з джерел водопостачання для народного господарства, а саме озеру Катлабух.

Озеро Катлабух використовується як основне джерело зрошення для трьох державних систем – Суворівської, Ізмаїльської та Кислицької (в минулому Кіровської) зрошувальних систем (ЗС) і ділянок малого зрошення (ДМЗ) на площі 16671 га. Окрім цього водами озера додатково заповнювалися Лощінівське, Камінське, Банівське і Муравлівське водосховища для зрошення 22063 га в межах Лощінівської, Ташбунарської, Муравлівської і Банівської ЗС і прилягаючих до них ДМЗ.

Метою роботи є аналіз гідрохімічного стану і оцінка якості води за агрономічними критеріями за більш тридцятирічний період одного з озер, води котрого використовувалися і продовжують використовуватися для зрошення і інших господарських потреб.

Для вирішення даної проблеми зібрані і оброблені матеріали гідрохімічних спостережень. Основні показники аніонного і катіонного складу, показник мінералізації і pH зведені і опосередковані за кожні п’ять років з 1991 по 2020 роки. Окремо наведені дані за 2021 рік. Для оцінки якості води по агрономічним критеріям були обраховані всі показники за останньою методикою. Визначені основні причини погіршення якості води.

Ключові слова: якість води, агрономічні показники, зрошувальна вода, мінералізація, водойма.

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