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Water Quality of Lake Iskanderkul and Its Tributaries

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Abstract

This article presents the study results of the change dynamics in the chemical composition of water in Lake Iskanderkul and the rivers flowing into it, as well as the comparison of water quality in the water bodies of the Iskanderkul Basin and several mid-stream tributaries of the Zarafshan River. It was established that the chemical composition of water in Lake Iskanderkul and its tributaries meets the requirements of the corresponding state standard (GOST 2874-82 "Drinking Water"). However, in terms of dissolved oxygen, copper, zinc, lead and iron the water in Lake Iskanderkul does not satisfy fish farming requirements. The main water pollution sources in the area include such natural phenomena as floods, avalanches, mudslides, and rock dissolution.

Keywords: chemical hydrology (hydrochemistry), water quality, Iskanderkul, water resources, Zarafshan.

1. Introduction

Under natural conditions, water's chemical composition is regulated by natural processes. The entry of chemical elements into water and their removal from it are maintained in equilibrium. Industrial, household and agricultural wastewater discharged into water bodies causes major changes in their hydrochemical and biological regimes, altering the overall water quality (Uniform Methods..., 1971). Thus, preservation of the required water quality in all water sources constitutes one of the most crucial issues of water management.

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The Zarafshan River Basin ranks the 2nd after the Pamir by the number of lakes (Abrorov, 2003). In total, there are 60 (sixty) lakes in the watershed with the total area of 9.18 km^2. A comprehensive study of the Zarafshan Basin lakes is of high social and economic importance (Nikitin, 1987; Abrorov, Shermatov, 2013). Surface water pollution observations are carried out in locations exposed to anthropogenic economic activity; background observations are carried out in the areas of minimal pollution, i.e. nature reserves, parks, and national parks. Lake Iskanderkul is one of the most important recreational and tourist sites in Tajikistan. On the one hand, the chemical composition of river water in the Iskanderkul Basin is predetermined by the commonality of the area's main meteorological conditions; on the other hand, it is subject to differing geomorphological profile, composition of constituent rock mass, volume and composition of runoff underground component, lake percentage and marshiness of certain basin sections, intensity of biochemical processes of rock weathering, as well as mineralization of organic matter. Transfer of chemicals into the lake with river water can be considered an integral indicator of natural conditions and economic activity inside the watershed (Abrorov, Shermatov, 2013; Kurbonov, Normakhmedova, 2017; Kurbonov, Normatov, 2018).

Water quality monitoring in water recreation sites, as well as detection and timely elimination of pollution sources are essential for averting the drivers contributing to the disruption of natural dynamics of geo-ecological system development. Recently, along with environmental challenges, preventing the lake's contamination with chemical elements and compounds has also gained urgency as to preserving the lake in its natural condition. However, reliable chemical hydrology data – neither for Lake Iskanderkul, nor for the entire water artery of the Zarafshan River Basin – are available currently (Kurbonov, Normakhmedova, 2017; Kurbonov, Normatov, 2018; Normatov et al., 2016).

Based on the above, the research aimed to compare the chemical composition of water in the water bodies of Iskanderkul Basin and several mid-stream tributaries of the Zarafshan River.

2. Research area

The target sites are mainly located in the depression in the southwestern part of the Zarafshan and on the northern slopes of the Gissar Ranges, in the valleys of the Magiyan, Kishtut (Shing), Pasrud Rivers and around Lake Iskanderkul. Shing Gorge Lake has a sophisticated chemical composition and contains Cl, SO_4, CO_3, HCO_3, Ca, Na, K, and Mg ions, as well as hydrogen and hydrogen sulfide (Abrorov, 2003; Abrorov, Shermatov, 2013; Kurbonov, Normatov, 2018).

Fig. 1. shows the location of the target water bodies in Iskanderkul Lake and Zarafshan River Basins.

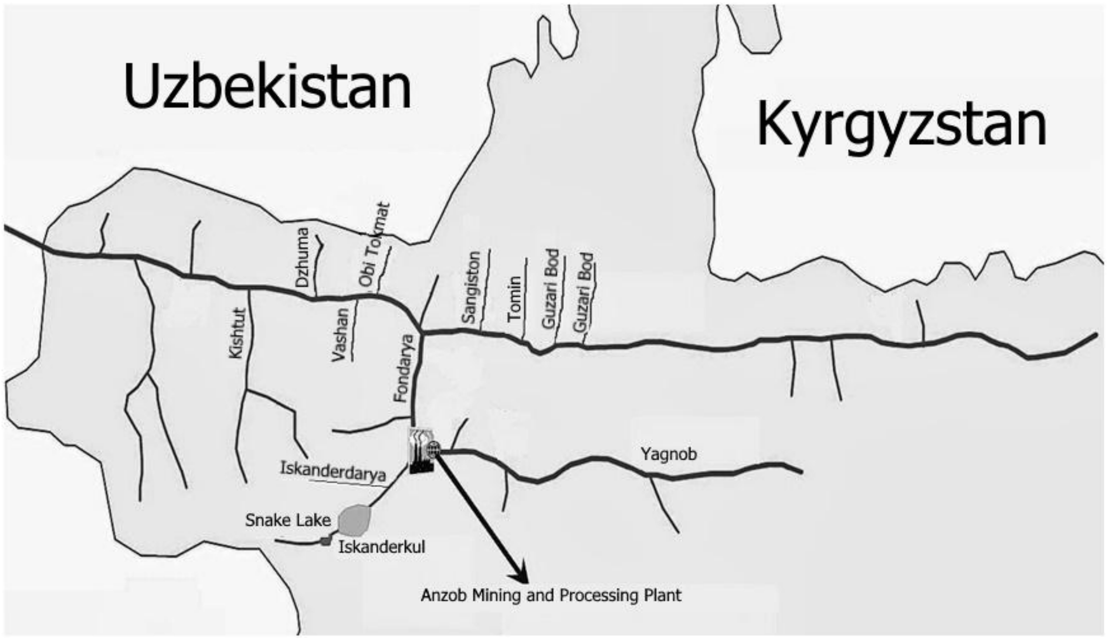

Figure 1. Location of water bodies in the Zarafshan River Basin (vicinity of Anzob Mining and Processing Plant and Lake Iskanderkul).

Iskanderkul is the largest, most beautiful and popular lake in Sughd Region of the Republic of Tajikistan. It is located in the northwestern part of the country and the southern part of Sughd Region at the altitude of 2,195 m ASL. Its depth reaches 72 meters, and the area is 3.4 km^2 (Abrorov, 2003; Nikitin, 1987).

Iskanderkul is an avalanche-type triangular-shape lake formed by rock damming of an ancient ice valley as the result of moraine deposition and mountain slide. Its shores are mostly steep, cliffed in some places, with four terraces (at 17, 35, 90 and 117 m ASL) pointing to higher water levels in the past (Abrorov, 2003; Nikitin, 1987).

The amount and composition of substances coming from the catchment formation zone are among the main factors affecting the chemical composition of Lake Iskanderkul's water, with the inflowing rivers serving the key transportation routes. In addition to multiple small mountain rivers, the Saratog, Khazormesh, Konchoch, Arg, Pareshon, Dukdon and Soming Rivers also drain into the lake. The Iskanderdarya River flows out of the lake. After 30 km it confluences with the Fondarya River – one of the main tributaries of the transboundary Zarafshan River.

The Iskanderdarya River originates from Lake Iskanderkul forming the 20 km valley and the 950 km^2 basin. The river's width in its upper reaches is 2.7 m, and 5 m in its lower reaches. The river's depth is 1.8 m in the upper reaches and 1 m in the lower reaches. The river's bottom is rocky. The Iskanderdarya is a snow- and glacier-fed river with the mean long-term discharge (at lake outlet) of 19 m^3/s. It flows mainly in the northeastern (eastern and northern in short upstream sections) directions. Water turbidity amounts to 16 g/m (Abrorov, 2003; Nikitin, 1987; Abrorov, Shermatov, 2013; Kurbonov, Normakhmedova, 2017).

The Agency for Hydrometeorology (AHM) of Tajikistan has a weather station on Lake Iskanderkul's shore to monitor the meteorological conditions in its proximity (Normatov et al., 2016). The local mean annual air temperature has been increasing from 6.2°C in 1960-1970's up to 7.2°C in 2000-2010. The average annual precipitation remains stable at 310 mm. The nature of meteorological changes reflects the atmospheric air temperature and precipitation only in the lake vicinity and is not common throughout the Zarafshan River Basin. That is, due to the relief the watershed demonstrates a rather complex original climate pattern in each separate gorge and river sub-basin (Abrorov, 2003; Normatov et al., 2016).

3. Chemical hydrology

As per G.A. Maksimovich's classification of natural waters based on the allocation of hydrochemical facies (Kurbonov, Normatov, 2018), Lake Iskanderkul is located in the zone of mountainous territories of hydrocarbonate hydrochemical formation with predominating calcium hydrocarbonate waters; in the scientist's table, it's water is described as follows:

Formation	Hydrocarbonate
Facies	$HCO_{3-} – Ca^{3+} – SO_4^{2–}$
Mineralization, mg/L	80-200

The latest observations on Lake Iskanderkul by the AHM staff were carried out four times (June 12, July 20, September 02 and November 08) in 2003. They detected a slight excess of MAC for magnesium – 57.55 mg/L (50 MAC) and iron – 0.42 mg/L (0.3 MAC). According to the Water Pollution Index (WPI), the lake's water belongs to Class II pure water. The findings of the 2003 observations executed by Tajikistan's AHM are shown in Table I below.

Table I. Characteristics of surface water pollution (mg/L) of Lake Iskanderkul, 2003.

Parameter	Measurement unit	12.06	20.07	02.09	08.11	Annual mean	MAC (drinking water)
Transparency	m	>23	>23	>23	>23	>23	-
Nitrites	mg/L	-	0.001	0.007	0.015	0.009	3
Nitrates	mg/L	2.8	2.1	3.2	3.1	2.85	45
Silicon	mg/L	5.8	0.7	1.48	1.3	2.73	10

Table I (continued)

Parameter	Measurement unit	12.06	20.07	02.09	08.11	Annual mean	MAC (drinking water)
Iron	mg/L	0.42	0.05	0.06	0.05	0.175	0.3
HCO_3	mg/L	156.4	108.0	72.0	17.0	87.8	-
Chlorides	mg/L	47.65	18.0	3.5	3.2	20.5	350
Sulfates	mg/L	39	-	-	-	39	500
Calcium	mg/L	29.68	15.0	16.8	-	22.8	100
Magnesium	mg/L	129.0	10.6	26.7	25	57.55	50
Na, K	mg/L	-	20.75	-	-	20.75	-
Phosphorus	mg/L	0.021	0.01	0.04	-	0.023	0.1
Chromium	mg/L	0.03	0.022	0.01	0.009	0.018	0.5
Fluorides	mg/L	0.14	0.02	0.17	-	0.12	1.5
Zinc	mg/L	0.19	0.17	-	-	0.18	5.0
Cuprum	mg/L	0.16	0.05	0.03	0.026	0.07	1.0
∑ Mineralization	mg/L	413.9	173.3	-	-	293.6	1,000
Total water hardness	mg-equ/L	1.54	1.61	1.9	-	1.6	7
pH		7.9	6.95	7.45	8.5	7.9	6-9

Source: (Normatov et al., 2016).

4. Materials and methods

To monitor and evaluate the contamination characteristics of Lake Iskanderkul's water, several water samples were taken at the mouth of the Saratag River in June-July 2017 and directly from the lake in July-August 2017. Further, the samples were compared with the chemical water parameters of other water bodies of the Zarafshan River Basin, namely the Fondarya, Yagnob, Kishtut, Sangiston, Shavatkh, Guzari Bod, Tomin, Obi Tokmat, Vashan and Dzhuma Rivers. Surface water (rivers, lakes, artificial reservoirs) quality monitoring was carried out via the hydrochemical network in accordance with the rules establishing uniform requirements for organizing and conducting the observations and processing of obtained data (Unified Methods..., 1971).

5. Results and discussion

The agricultural sector in the area is developed poorly (Abrorov, 2003; Abrorov, Shermatov, 2013) and, thus the basin's hydrochemistry is predetermined by the rock mineralogy in the catchment formation zone. The upper reaches of the Zarafshan River, especially the Fann

Mountains – where Lake Iskanderkul Basin is located – feature a complex mountain-gorge and high-mountain relief leading to significant variation in the chemical composition of water bodies (Table II).

Table II. Water characteristics in the Zarafshan River Basin.

Date/ time of day	Title	t, °C	pH	σ*	ppm	mg/L						
						O_2	NO_3	NO_2	PO_4	NH_4	Pb	Zn
May 08, 2017/ 18:00	Snake Lake	12.6	8.5	263	132	10.5	0.0	0.0	0.0	0.0	0.0	0.0
May 09, 2017/ 10:20	Iskanderdarya	12.1	8.6	189	94	10.5	17.5	0.0	10.0	0.0	0.0	0.0
May 09, 2017/ 11:50	Yagnob	13.6	8.5	209	105	6.0	5.0	0.0	250	0.0	0.0	0.0
May 09, 2017/ 12:50	Fondarya	14.8	8.4	208	102	6.0	0.0	0.0	225	0.0	0.0	0.0
May 10, 2017/ 10:00	Shavatkh	9.7	8.5	163	80	7.0	10.0	0.0	25.0	0.0	0.0	0.0
May 10, 2017/ 13:35	Guzari Bod	14.2	8.4	212	107	3.0	10.0	0.0	50.0	0.0	0.0	0.0
May 10, 2017/ 14:10	Tomin	11.7	8.4	201	100	5.0	10.0	0.0	25.0	0.0	0.0	0.0
May 10, 2017/ 14:45	Sangiston	16.0	8.3	209	103	5.0	10.0	0.0	100	0.0	0.0	0.0
May 10, 2017/ 18:45	Obi Tokmat	13.5	8.4	272	134	6.0	5.0	0.0	0.0	0.0	0.0	0.0
May 11, 2017/ 11:30	Vashan	14.2	8.3	450	226	4.0	10.0	0.0	75.0	0.0	0.0	0.0
May 11, 2017/ 12:30	Kishtut	22.0	8.5	320	160	6.0	10.0	0.0	375	0.0	0.0	0.0
May 11, 2017/ 18:00	Dzhuma	26.4	8.4	958	479	7.0	25.0	0.0	25.0	0.0	0.0	0.0
	MAC**	-	6-9	-	-	-	45	3	-	2	0.03	5.0

*σ – electrical conductivity;

**MAC for drinking water as per (GOST 2874-82 "Drinking Water").

The analysis results for the water samples taken in the most important sites – Lake Iskanderkul and the mouth of the Saratag River – are presented in Table III below. The water of Lake Iskanderkul demonstrated low mineralization, satisfactory oxygen regime, percentage saturation within 51-83%, organic matter content below 2.4 mg/L, as well as insignificant biogenic and other components' content.

Table III. Characteristics of water pollution at the mouth of the Saratag River and in Lake Iskanderkul (2017).

Parameter	Unit	MAC*	Mean/Saratag	Mean/Iskanderkul
Water t^o	degree Celsius		27.50	28.95
Color	degree	20 (45)	45.00	50.00
Turbidity	FTU	26	15.50	12.50
Odor	point	2	0.00	0.00
pH		within 6-9	7.45	7.78
Eh-	µS/m	36.3	24.85	31.15
Nitrites	mg/L	3	0.00	0.01
Nitrates	mg/L	45	0.16	0.33
NH_4	mg/L	2	0.01	0.00
Fe	mg/L	0.3	0.04	0.04
P	mg/L	0.1	0.00	0.00
Al	mg/L	0.5	0.00	0.00
Cl_2	mg/L	350	0.04	0.04
Mn	mg/L	0.1 (0.5)	0.00	0.00
Si	mg/L	10	2.44	1.33
SiO_2	mg/L	6	5.05	6.25
SO_4	mg/L	500	44.50	26.50
Ca	mg/L	100	24.80	29.30
Mg	mg/L	50	14.80	0.00
Cu	mg/L	1	0.00	0.00
$Cr_{(IV)}$	mg/L	0.5	0.00	0.00
Fluorine	mg/L	1.5	0.38	0.38
Lead	mg/L	0.03	0.00	0.00
Selenium	mg/L	0.01	0.00	0.00
Total hardness	mg-equ/L	7	1.93	1.43
∑ Mineralization	mg/L	1000	204.50	161.50

*MAC for drinking water as per (GOST 2874-82 “Drinking Water”).

The data in Table III show that the majority of values – at the Saratag’s mouth and in Lake Iskanderkul – slightly differ from each other. According to the results of the analysis presented in Table III, it is possible to state that the water up to the lake, i.e. at the mouth of the Saratag River, is more turbid compared to the lake water. The amount of dissolved substances contained in the water, i.e. total mineralization, varies slightly (with the mean of 204.5 mg/L at the Saratag’s mouth, and 161 mg/L in Lake Iskanderkul). The largest contribution to the total water mineralization falls on inorganic salts (chlorides, calcium sulfates, magnesium, potassium and sodium), as well as a small amount of organic matter. Water hardness in the target water bodies is the result of dissolution of calcium- and magnesium-containing rock mass.

According to the data obtained, the lowest water turbidity in the lake is observed in winter; the highest in spring during floods; and in summer during rains and active growth of the smallest living organisms and algae floating in water. In addition to the thinly dispersed suspensions coming from the surrounding slopes, water turbidity can be caused by a wide spectrum of causes like presence of carbonates, aluminum hydroxides, high-molecular organic impurities of humus origin, emergence of phyto- and zooplankton, as well as oxidation of iron and manganese compounds by atmospheric oxygen.

Based on the obtained results (Table III), by all indicators water quality in Lake Iskanderkul and the mouth of the Saratag River complies with the requirements of State Standard GOST 2874-82 “Drinking Water" (GOST 2874-82 “Drinking Water”, 1985). According to the data received, the annual mean of the total water hardness of Lake Iskanderkul amounts to 1.6 mg/L and meets the requirements of the drinking water quality standards, i.e. SanPiN 2.1.4.1074-01 “Drinking Water of Centralized Water Supply Systems” (Drinking water quality requirements (SanPiN 2.1.4.1074-01)), although during certain months a slight excess of iron due to the additional water suspension increase can be observed.

Comparing the parameter changes (Table I and Table III) over time demonstrates that in 2017 the water of Lake Iskanderkul has become cleaner than in 2003 by almost all parameters. This might be due to the increased mean annual temperature in the area and, thus reduction of the quantity of atmospheric precipitation that, in its turn, led to the reduction of the number of floods, avalanches and mudflows in the lake’s vicinity in recent years.

Comparing the results of analyses of water samples from the Zarafshan River Basin (Table II) with the water of Lake Iskanderkul and Saratag River (Table III) allows stating that the nitrate content in the former is much higher than in the latter. Since the Zarafshan River Basin is home to numerous settlements, such a high level of nitrate pollution may be due to anthropogenic sources, including the main ones – discharge of household wastewater and farmland runoff where nitrogen fertilizers are used.

6. Conclusions

Assessment of the quality of water bodies represents the most important phase of developing the recreational opportunities in the Zarafshan Basin. Precise knowledge of the water state allows effectively planning the supply of vacationers with high-quality drinking water. The research allowed establishing the following facts:

1. In terms of quality and chemical composition, by all indicators the water of Lake Iskanderkul and the rivers flowing into it meets the requirements of the state standard (GOST 2874-82 “Drinking Water”);
2. The lowest lake water turbidity is observed in winter, the highest in spring during floods and in summer during rains and development of the smallest living organisms and algae floating in the water;
3. The main causes of water pollution in the area include such natural phenomena as floods, avalanches, mudslides, and rock dissolution.

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