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**THE ECOLOGICAL-TOXICOLOGICAL CONDITION OF THE
WATERS IN THE SOTK AND MASRIK RIVERS AND IN THE
ARABLE LANDS OF THE NEIGHBORING AGROCENOSIS UNDER
THE INFLUENCE OF THE SOTK MINE EXPLOITATION**

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Upon the investigations it has been disclosed that along with the increase of the dimensions in the mining industry, as well as with the increase of rock dump amounts, the organoleptic and chemical indices of the waters in the Sotk and Masrik rivers have also grown up. The amount of suspended particles per liter of water has increased for the last 10 years by 210%...317.0% or by 32.1 *mg/l* in the waters of the Sotk River and by 13.2 *mg/l* in the Masrik River. Similar changes have also been observed in the indices of nitrates, sulphates and hydrogen values, which are mainly related to the chemical composition of the mountainous rocks, where the alkaline chemicals mainly predominate (Ca, K, Na, Mg, etc.) and also to the intensive agricultural activities conducted in the given area, particularly in the riverine areas, as well as to the development of the livestock sector.

Meanwhile, it has been found out upon investigations that both in the previous 10 years and similarly in 2019, the content of heavy metals and other chemical elements in the Sotk and Masrik Rivers and in the lands of their adjacent agroecosystems, the total intensity of their geochemical stream considerably varied and fluctuated related to the exploitation of the Sotk mine and to the changes of the ore mining dimensions. To reduce the mobility of heavy metals and to improve the ecological-toxicological conditions of the mentioned rivers and ploughlands irrigated with those waters, it is necessary to continuously add the lime amount CaO in the acidic drainage of the mining site so that the water environment reaction would hold up at least within the range of 9 (pH 9). Besides, individual heavy metals (such as tungsten, molybdenum, vanadium, etc.) are more active in the alkaline medium, hence, for their refining it is necessary to install filters as well.

Keywords: mining industry, water system of the Sotk and Masrik Rivers, ploughlands, organoleptic properties, heavy metals, contamination.

Introduction. The Sevan basin management area is situated in the eastern part of Armenia. The basin of Lake Sevan makes up one sixth of the total territory of Armenia. The Sevan basin management area makes 4721 square *km*, out of which 1279 square *km* is covered by the mirror of Lake Sevan (due to the data provided by "Armhydromet" SNCO, 2017). Lake Sevan is surrounded by Geghama (from the West part), Vardenis (from the South part), Areguni (from the

North-Eastern part), Sevan and Eastern Sevan (East part) mountain chains with up to 3598 *m* elevation (Vardenis). The Sevan basin management area stretches from 39°87' to 40°68' in the northern latitude and from 44°76' to 45°98' in the eastern longitude. The maximum length from the south-north makes 90 *km*, while from the east to west – 103 *km*. One of the characteristic traits of the Sevan basin management area is that the ratio between the catchment/drainage basin area of Lake Sevan and the area of the river mirror is rather small (3:1) as compared to other large lakes (averagely 10:1).

Twenty nine rivers and streamlets (including large springs in the river form) flow into Lake Sevan and only the Hrazdan River originates from the lake. In general, most of the rivers in the basin of Lake Sevan have a length of less than 10 *km*. There are only 6 rivers with a length of 26 *km* and the Argichi river is the only one with a length of more than 50 *km*, the rivers Sotk and Masrik with a length of 10 *km* each are situated in the north-eastern part of the lake and to a certain extent are fed by the neighboring areas of the Sotk mine. The waters of the mentioned rivers are used mainly for irrigation purposes, while the excess amounts are discharged into Lake Sevan.

Mining industry has always been and is still a powerful factor for destabilization of the ecological conditions in the areas of all countries over the world, as a result of which the natural relief and hydrological regimes are disturbed, the vegetative cover is destroyed, a huge amount of rock dumps and technological effluents/waste waters are generated, which are piled up in the canyons and tailing dams; the environment is contaminated with heavy metals and other substances and the population's health is strongly damaged.

Heavy metals are on the top position (28%) from the prospect of their ecological threats and environmental risk exposure. The world practice evidences that the heavy metals are one of the most toxic pollutants, the danger of which is related to their stability in the external environment, to their water-solubility and to the great ability to accumulate in the soil and plants [1-5].

In the water environment the pollutants can be dissolved, molecular, ionic, colloidal and suspended [6-8]. Heavy metals pose great danger for the mentioned environment, which appears mainly in the form of suspensions. Unlike the atmosphere, where the retention capacity of heavy metals is not high, the surface waters are mostly considered the conservative component of the environment. The content of zinc in the surface waters is higher than the content of cadmium by 1...2 degrees; the content of the discussed elements is higher in the surface waters than in the seas and oceans. In the streaming waters about 90% Zn and 65% cadmium (Cd) are in a suspended state [9,10].

Thus, the evaluation of the ecological state and the contamination level of the surface waste waters and the land areas irrigated with those waters, flowing from the areas of mining industry and from their neighboring territories and the

related studies are actual and are based on the strategic development requirements of the given region; at the same time, they have both environmental and socio-economic feasibility and address the interests of population by ensuring their healthcare and safety. Though only ore mining and transportation activities are implemented in the RA Sotk gold deposit (gold mineralization and extraction from the ores is implemented in the Ararat gold flotation plant), laying of the rock dumps appeared throughout the process of the aforementioned activities, the spread of dust and aerosols in the environment through the atmospheric streams, particularly in the waters of the Sotk and Masrik Rivers (the latter are used for irrigation purposes, the rest of the water is discharged into Lake Sevan) situated in the territories near the mining site, cause pollution with different types of ions and heavy metals. Hence, we have set a task to study and identify the ecological state of these waters and therewith irrigated land areas and to make appropriate recommendations for its improvement.

The Problem statement and justification of the method. The studies have been conducted through the water and soil sampling from the respective observation points of the Sotk and Masrik Rivers and from the adjacent lands situated near the Sotk mine and through determining their organoleptic and chemical indices. It has been planned to determine the dynamics of the investigated elements by comparing the obtained data with the similar indices of the water and soil samples taken from the same observation point by the Environmental Monitoring and Information Center (SNCO) under the Ministry of Environment within the previous 10 years and to accordingly develop the needed recommendations.

Taking into account the circumstance that reoxygenation, as well as physicochemical, biochemical processes and intensive microbial activities, sorption, desorption and other activities are taking place in water, besides, the water organoleptic properties can change, the laboratory studies on taste, flavor, color, permeability have been conducted with the standard methods [11,12]. Hydrogenic index, specific electrical conductivity and salinity have been determined through the electro-chemical method: the total dissolved substances have been calculated by multiplying the value of specific electrical conductivity with 0.65.

Biochemical oxygen demand (BOD) represents the amount of oxygen (*mg*) needed for oxidizing organic matters in 1 liter water at 20°C under aerobic conditions over some period of time: in our case it has been determined for 5 days [11,12].

Biochemical oxygen demand (BOD) (bichromatic oxidation) has been determined in the acidic medium of potassium bichromate under the guidance of catalysers, while titration has been implemented with 0.025 N solution of the Mohr's salt. It has been determined through the following formula: $Cx = (n_1 - n_2) \times$

$\times 8 \times V_2/V_1 \times \times 1000$, where V_1 is the volume of the investigated water, V_2 is the volume of the potassium bichromate, n_1 is the volume of the Mohr's salt when titrating the zero sample and n_2 is the volume of the Mohr's salt when titrating the sample. In drinking water the rate of BOD makes $15 \text{ mg O}_2/\text{L}$, while in the sanitary and irrigation waters it makes $30 \text{ mg O}_2/\text{L}$ [12]. Ammonium, silicium, nitrate and phosphorus ions have been determined with KFK-2 spectrophotometry (Shimadzu 1650) at the wavelength of 360...600, 410, 536 and 708 nm respectively. Sulphate, chloride, nitrate ions have been determined through the ion chromatography method (DIONEX - 1000), while the hydrocarbonate- through the back-titration method [12].

The permeability, flavor, color are technical criteria, which have been determined through the visual and sensory methods. The analysis of the chemical elements (Li, Be, B, Mg, Na, Al, P, K, Ca, Se) in the water samples have been conducted through the inductively coupled plasma mass spectrometry (ICP-MS, ICP-MSELAN 9000) in line with the standard of ISO 17294, which is based on the use of argon inductively coupled plasma as a source for ions and the use of mass spectrometry for ion separation and their further determination [12-14].

The spectral analysis of heavy metals and chemical elements in the soil samples have been conducted with the X- 5000 XRF drift detector through SDD analyzer, which involves three regimes: a model for identifying metals with small concentrations in water, soil and powdery samples, a model for the analysis on the mine rock samples and an empiric model. After sifting the air-dry soil sample with 0.5 mm sieve, it is bagged in the device which contains an automatic fluorescence X-ray system, which works through batteries and is connected to the computer, which, in its turn, demonstrates the indicators upon the analytical software upon the background of chemical elements involved in the standard sample.

The results of the research. Upon the results of investigations it has been disclosed that the organoleptic indices, (permeability, suspension particles, color and flavor) both in the Sotk and Masrik Rivers, are different depending on the sampling times. The water quality deteriorates starting from May up to November, which is related to the rain and meltwaters, as well as to the intensive atmospheric activities. It is apparent that less amount of suspended particles in the waters of the Sotk and Masrik Rivers are found particularly in the water samples taken from the territories closer to the mining site. Thus, in November (2019), the suspended particles in the water samples taken from the territory situated 1km above the Sotk community and opposite the community have made 3.5 mg/L and 11.5 mg/L respectively (Table 1), while in the waters of the Masrik river 1.5 km above V. Shorzha community and opposite the mentioned community it has made 5.5 and 19.9 mg/L respectively; at the friths of the Sotk and Masrik rivers and after interflowing of the waters their suspended particles amounted to 47.5 and 28.7 mg/L respectively (Tables 1,2).

If we compare the mentioned indices with the similar average data of the last previous 10 years, it becomes obvious that along with the increase of the mining industry dimensions, as well as with the increase of the rock dumps amount, the quantity of the suspended particles have also grown up and, as to the mentioned studies, the amounts of the suspension particles per liter of water have increased by 210.2...317.0 % as compared to the water samples taken within the same period in 2010, or to be more precise, in waters of the Sotk River they have increased by 32.10 *mg/L* and in waters of the Masrik River – by 13.2 *mg/L* (Tables 1,2). The suspension particles have a great impact on the water permeability, its color, flavor, as well as on its biological and bio-chemical indicators, which is more clearly described in the tables below.

Electrical conductivity is considered to be one of the vital ecological indicators of the surface waters. As we can see from the data of Tables 1 and 2 provided upon the studies of the Environmental Monitoring and Information Center, the values of electrical conductivity in the Sotk and Masrik Rivers grow for the period of December-March comparing to those observed for the period of Spring-Autumn. The mentioned data testify that in the winter hydrological period, the river flow is resulted from the feeding of ground and underground waters and their hydrochemical quality is formed by the hydrochemical influence of the waters just mentioned. Considering that unlike the river waters, the values of electroconductivity in the waters of cellar pits practically remain unchanged in that period and have 2...2.5 times higher values than those recorded in the river waters, it can be concluded that in the period of December-March the hydrochemical composition in the waters of the Sotk River is also affected by the drainage waters of the mining site and cellar pits.

The results of the laboratory studies show that in the waters of left-bank tributary of the Sotk and Masrik Rivers, the feeding of which hardly has any relation with the Sotk mine, the average value of electroconductivity is lower 2...4 times than the values generally recorded in the waters of the mentioned rivers. For comparison, the values of the electroconductivity in waters of the Karchaghbyur River mouth (frith) have been also studied, which don't have any seasonal variabilities and are 2 times lower than the average electroconductivity value observed in the waters of the Masrik River mouth.

The investigated waters are equivalent to the alkaline waters regarding the values of their hydrogenic indicators (pH). Thus, pH in the Sotk River mouth (frith) makes 8.78, in the water sample taken from 1.0 *km* above the Sotk community, it is 8.43, while in the Masrik River mouth it is 8.38 and in the samples taken from the same river, 1.5 *km* above V. Shorzha community, it makes 8.21. This circumstance is related to the chemical composition of the environmental mountain ores, where the alkaline chemical elements (Ca, K, Na, Mg, etc.) are

prevailing, the content of which has always been high both in the period of 2010-2018 and in the period of our investigations.

The Sotk River waters contain on average 30.2 *mg* Ca, 1.3 *mg* K, 5.5 *mg* Na and 31.6 *mg* Mg per liter of water, while in the waters of the Masrik River, the mentioned indices make 22.5; 2.0; 6.3 and 5.4 *mg/L* respectively. The content of Ca is 26.00 *mg/L*, K - 2.60, Na - 6.45 and Mg- 5.20 *mg/L* (Tables 3 and 4), the mineralization degree in the waters (total amount of the inorganic compounds) doesn't exceed 1 *g/l* and, per the average data of the previous 10 years, it makes 129.8 *mg/L* (in the waters of the Masrik River), 263.4 *mg/L* (in the waters of the Sotk River), for the period of our investigations (November, 2019) the mentioned index in the waters of the Masrik River has made averagely 146,9...182,0 *mg/L* and in the waters of the Sotk River it makes 230.8...253.5 *mg/L*. Besides, 95...96% are hydrocarbons; 4...5% are sulphates, while Se and Al are of very little amount. As to the content of nitrate, nitrite and ammonium ions it is clear from the Table data that upon the results of the investigations conducted in the previous years and upon the laboratory investigations on the water samples conducted in November, 2019, they hardly exceed the standards set through the decision 75N on the surface waters assessment, taken on January 27, 2011, by the RA Government, which make NO_3^- – 45, NO_2^- – 3.3, NH_4^+ - 2 *mg/L* and NO_3^- - 0.02...1.5, NO_2^- - 0.001...0.04, NH_4^+ - 0.03...0.7 *mg/L* respectively.

The data of EMIC (Environmental Monitoring and Information Center) testify that for the Winter-Spring period, in the waters of all observation points, the concentration of nitrates grow parallel to the intensification of water flow as well. In the waters of cellar pits, unlike in those of the rivers, the concentration of the nitrate almost stays the same and it is 2...4 times lower, and hence, the effect of the drainage waters in the cellar pits is insignificant, while there are more considerable factors forming the content of nitrates in the river waters, which are mostly related to the anthropogenic factors and the fluctuation of temperature. The increase of the nitrate content is mainly conditioned by the intensive agricultural activities implemented in the given areas, particularly in the riverine land areas, as well as, most likely, by the development of the livestock sector. As a result of the single mineral fertilization with nitrogen, some part of the nitrogen is leached and moved into the river mingling with the river waters. At the same time, some part of the cattle manure and liquid manure is imbibed into the soil and the other part is leached with the atmospheric precipitations, gets mixed with the river waters increasing the nitrate content.

Table 1
Organoleptic and chemical indicators of the Masrik River waters depending on the exploitation of the Sotk gold mine

n/n	Indicators	Measuring unit	October-November, 2010				October-November, 2015				November, 2019			
			The indices of cellar pit, October-November	1.0 km above the Sotk community	Opposite the Sotk community	River mouth (frith)	The indices of cellar pit, October-November	1.0 km above the Sotk community	Opposite the Sotk community	River mouth (frith)	1.0 km above the Sotk community	Opposite the Sotk community	River mouth	After interflowing of the Sotk and Masrik Rivers
1	Hydrogenic index		8.30	8.20	8.40	8.74	8.40	8.36	8.44	8.40	8.43	8.37	8.35	8.78
2	Dissolved oxygen	mg/L	10.20	9.20	6.40	10.30	9.8	6.40	7.60	6.60	7.20	6.80	9.30	5.40
3	BOD ₅	mgO ₂ /L	1.80	2.00	1.30	2.20	2.0	2.15	2.18	2.10	1.79	1.00	2.70	1.91
4	BOD	mgO/L	-	-	18.0	-	15.40	28.0	15.0	27.0	15.0	35.00	17.00	30.0
5	Total phosphorus	mg/L	0.02	0.01	0.05	0.00	0.03	0.05	0.01	0.05	0.02	0.02	0.01	0.04
6	Ammonium ion	mgN/L	0.30	0.25	0.19	0.18	0.41	0.14	0.09	0.14	0.23	0.12	0.14	0.19
7	Nitrite ion	mgN/L	0.01	0.00	0.01	0.01	0.06	0.04	0.03	0.03	0.00	0.00	0.01	0.04
8	Nitrate ion	mgN/L	0.00	-	1.31	-	0.01	2.23	0.26	2.18	0.37	0.45	3.46	2.44
9	Phosphate ion	mg/L	0.05	0.05	0.10	0.05	0.07	0.18	0.03	0.17	0.00	0.01	0.17	0.07
10	Chloride ion	mg/L	2.65	2.34	2.31	8.30	2.45	5.26	1.62	5.13	2.43	3.27	7.96	7.58
11	Sulphate ion	mg/L	20.40	21.64	28.45	65.11	19.62	30.30	8.46	29.30	6.80	15.75	41.53	43.37
12	Total dissolved salts	mg/L	239.0	246.4	306.0	299.6	261.4	330.0	202.0	309.0	210.0	230.8	285.0	253.5
13	Electroconductivity	mSm/cm	829.0	379.0	470.0	461.0	972.4	507.0	311.0	502.0	323.0	355.0	439.0	390.0
14	Suspended particles	mg/L	6.90	2.70	15.40	1.60	7.80	64.40	5.90	62.40	3.50	11.50	47.50	14.1
15	Permeability	cm	29	29	30	30	27	29	29	29	26	27	28	28
16	Color (visual)	degree	4	4	4	3	4	4	5	4	4	4	4	4
17	Flavor	point	Slight flavour 2	2	2	2	3	2	2	3	3	2	2	3

Table 2
Organoleptic and chemical indicators of the Masrik River waters depending on the exploitation of the Sotk gold mine

n/n	Indicators	Measuring unit	October-November, 2010			October-November, 2015			November, 2019				
			1.5 km above the community of V. Shorzha	1.5 km below the community of V. Shorzha	River mouth	1.5 km above the community of V. Shorzha	1.5 km below the community of V. Shorzha	River mouth	The mouth (firth) of the Karchagbnyr river	1.5 km above the community of V. Shorzha	1.5 km below the community of V. Shorzha	River mouth	0.5 km below the river mouth after interflowing
1	Hydrogenic index		9.20	9.00	8.49	8.50	8.41	8.14	7.3	7.88	8.38	8.24	7.55
2	Dissolved oxygen	mg/L	11.40	11.2	10.00	8.90	7.00	7.30	7.9	7.70	4.10	6.70	6.90
3	BOD ₅	mgO ₂ /L	2.80	2.4	2.80	1.62	1.00	1.33	1.2	1.50	1.05	2.60	2.15
4	BOD	mgO/L	-	8	5.00	8.00	11.4	18.0	10.4	10.0	30.00	15.00	20.0
5	Total phosphorus	mg/L	0.01	0.0061	0.1274	0.07	0.09	0.16	0.01	0.03	0.03	0.12	0.27
6	Ammonium ion	mgN/L	0.10	0.1012	0.1944	0.06	0.06	0.07	0.21	0.06	0.11	0.08	0.14
7	Nitrite ion	mgN/L	0.08	0.092	0.0276	0.01	0.03	0.06	0.13	0.00	0.00	0.03	0.11
8	Nitrate ion	mgN/L	-	0.5534	0.4944	0.33	0.56	0.93	0.03	0.26	0.76	1.43	2.76
9	Phosphate ion	mg/L	0.01	0.0142	0.3390	0.40	0.39	0.37	0.12	0.04	0.07	0.28	0.23
10	Chloride ion	mg/L	4.35	4.4061	4.6562	3.06	2.62	2.41	1.10	1.19	2.15	3.09	4.92
11	Sulphate ion	mg/L	11.61	11.69	16.54	5.16	5.81	6.96	10.4	4.06	6.96	15.01	20.97
12	Total dissolved salts	mg/L	152.1	152.60	156.6	154.0	162.6	176.00	114.2	69.0	146.90	141.00	171.00
13	Electroconductivity	mSm/cm	234.0	230.60	241.0	236.0	247.4	271.00	118.2	106.0	226.00	218.00	267.00
14	Suspended particles	mg/L	1.80	1.87	15.80	60.20	23.60	18.50	2.14	5.50	19.90	28.70	19.90
15	Permeability	cm	31	31	30	30	32	31	31	32	31	32	32
16	Color (visual)	degree	3	3	4	4	4	4	4	3	3	3	3
17	Flavor	point	Slight flavor 2	2	3	3	With flavor 4	4	3	3	3	3	3

A similar pattern is observed in case of the concentration dynamics in the sulphate ion, which also grows along with the water flow intensification. Unlike the river waters, in the waters of the cellar pits, the sulphate concentration practically remains the same and is 2...3 times lower. So, the recorded sulphate content in the waters of the Sotk and Masrik Rivers is formed under the influence of the Sotk mine exploitation, under the impact of pressure factors existing near the zone of the mining site along the south-eastern part of the Areguni mountain chain, as well as under the influence of the waters in the zone of the seepage flow (internal stream) of the Sotk and Masrik Rivers, particularly under the significant impact of right-bank ground and artesian (underground) waters of the catchment basin (Table 3,4).

Table 3

Content of individual chemical elements in the waters of the Sotk River by dates

n/n	Name of the chemical elements	Measuring unit	October-November, 2010			October-November, 2015			November, 2019			
			Above the Sotk community	Opposite the Sotk community	River mouth	Above the Sotk community	Opposite the Sotk community	River mouth	Above the Sotk community	Opposite the Sotk community	River mouth	After interflowing of the Sotk and Masrik Rivers
1	Ca	mg/L	35.09	40.07	50.97	37.91	21.87	28.15	20.35	23.02	46.04	34.32
2	Mg	mg/L	33.63	39.91	29.26	42.14	31.12	30.72	32.56	41.09	19.70	30.39
3	K	mg/L	1.18	1.68	5.49	2.77	0.52	5.47	0.48	0.93	2.07	2.45
4	Na	mg/L	3.06	6.07	11.38	3.83	2.68	10.86	2.72	6.35	7.58	11.70
5	Al	mg/L	0.06	0.03	0.04	0.06	0.02	0.56	0.02	0.02	0.12	0.14
6	Se	mg/L	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	<0.00	0.00
7	S/Sulphur/	mg/L	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01

While in the lower parts of the rivers the increase of the sulphate ion content is mainly related to the application of various agrochemicals during the agricultural farming, as well as to the vaccines administered throughout cattle breeding, its residuals are poured into the rivers flowing through the mentioned territories increasing the amount of the mentioned ions. The most concerning issues of the environmental pollution are related to the surface waters, which come forth as a transition medium, being carriers and conveyors of the technogenic pollutants, like heavy metals [15]. In this respect, the research results conducted on the chemical composition of the investigated waters are of utmost significance and purposeful,

especially when they are viewed and compared with the Maximum Permissible Concentration Limits (MPCL) determined for the studied elements in drinking and domestic waters, which are as follows: Hg – 0.0005; Cd – 0.001, Pb – 0.03; Be – 0.0002; Co – 0.01, Cu - 1, Zn - 5, Cr⁺⁶ – 0.05, Ni, Ba, Mn-up to 0.1 mg/L [16-18].

The research results have indicated that the content of heavy metals and other chemical elements in the Sotk and Masrik Rivers is significantly low or are in line with the MPCL as to the data gained upon the investigations conducted in November, 2019 and during the previous 10 years. Besides, we will get a more comprehensive view of the above-discussed issue, if we put forward the circumstance that within the study period the total intensity of the geochemical flow of heavy metals in the waters of the mentioned rivers significantly fluctuates and varies depending on the exploitation of the Sotk mining site and on the changes of the mining ore volumes.

Table 4
Content of individual chemical elements in the waters of the Masrik River by dates

n/n	Name of the chemical elements	Measuring unit	October-November, 2010			October-November, 2015			November, 2019			
			1.5 km above the community of V. Shorzha	1.5 km below the community of V. Shorzha	River mouth	1.5 km above the community of V. Shorzha	1.5 km below the community of V. Shorzha	River mouth	1.5 km above the community of V. Shorzha	1.5 km below the community of V. Shorzha	River mouth	After interflowing of the Sotk and Masrik rivers
1	Ca	mg/L	32.43	28.4	26.42	31.96	30.89	30.89	16.45	30.03	28.75	29.36
2	Mg	mg/L	6.61	8.40	9.16	5.82	8.86	8.86	2.31	6.78	7.55	11.22
3	K	mg/L	2.29	3.00	3.30	4.42	4.46	4.46	0.64	2.60	2.95	4.48
4	Na	mg/L	9.04	9.11	9.11	7.86	9.89	9.89	3.33	10.46	5.36	11.92
5	Al	mg/L	0.01	0.03	0.04	0.79	0.06	0.06	0.13	0.11	0.15	0.23
6	Se	mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	S (Sulphur)	mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The results of the soil sample analyses taken from the arable lands of agroecosystem located at the basins of the investigated rivers indicate that the land areas irrigated with the waters of the Sotk and Masrik rivers contain a high level of heavy metals, while in the soil samples taken from the land areas irrigated with the waters of Karchaghbyur River, hardly any quantity of heavy metals have been detected (Table 5).

Table 5

The average indices of heavy metals in the Sotk, Masrik and Karchaghbyur rivers and in the ploughlands irrigated with those waters

Name of the element	Name of the river and basin						Phytotoxic concentrations of heavy metals in the soil, mg/kg [15]
	Sotk		Masrik		Karchaghbyur		
	In waters, g/l	In ploughland, mg/kg	In waters, g/l	In ploughlands, mg/kg	In waters, g/l	In ploughlands, mg/kg	
Ag	<10 ⁻⁵	0.2	<10 ⁻⁵	0.8	-	-	2
As	0.080	14.3	0.045	17.0	-	0.012	15...50
Cd	<10 ⁻³	0.7	<10 ⁻²	0.9	-	-	3...8
Co	<10 ⁻⁴	10.0	<10 ⁻⁵	13.4	-	-	25...50
Cr	0.0080	4.6	0.0065	20.0	-	-	75...100
Cu	0.035	10.5	0.027	19.2	0.001	1.0	60...125
Hg	0.003	0.2	0.0015	0.3	-	-	0.3...5
Mn	61.3	980.0	59.4	640.0	-	traces	1500...3000
Ni	0.003	48.0	0.009	45.0	-	-	100
Pb	0.007	21.0	0.009	27.0	0.00004	0.7	100...120
Zn	0.020	90.0	0.87	78.0	0.0003	1.2	70...200
Sb	<10 ⁻⁴	2.0	<10 ⁻³	6.4	-	-	5...10
Se	<10 ⁻⁵	-	<10 ⁻⁴	0.7	-	-	5...10
V	0.035	1.4	0.026	3.0	-	-	5...100

The table data testify that the content of copper, zink, plumbum, hydrargyrum, arsenium and manganese is rather high in the land areas (20...25 cm soil layers) irrigated with the waters of the Masrik and Sotk Rivers, while the content of other metals is insignificant and is lower than the background indices of phytotoxic concentrations of the mentioned metals in the soil (Table 5). Whereas, neither the abovementioned metals, nor the other ones have been detected in the land areas irrigated with the waters of the Karchaghbyur River. This circumstance comes to prove once more that the Sotk and Masrik rivers are directly fed from the access of the Sotk mining plants. The heavy metals of the ores resulted from the leaching of the rock dumps (by means of precipitations) and dusts occurring throughout the mining plant exploitation penetrate into the river waters and the latter due to the peculiarity of heavy metal accretion, have accumulated in the soil strata of the ploughlands. The lack of heavy metals in the land areas inundated with the waters of the Karchaghbyur River is accounted for the fact that the feeding of this river is hardly connected to the mining site, hence, the chemical indices of the waters and the content of heavy metals are much lower or are missing at all. As it is mentioned in the table, in the waters of the Karchaghbyur River and in the soil samples taken from the land areas irrigated with those waters, there are negligible amounts of As, Cu and Zn, which are the result of the residual quantities of the

pesticides used in the agricultural fields, while the appearance of Pb is the result of the emissions from motor vehicles operating in this area.

Conclusions and recommendations. Summing up the conducted investigations we can draw the following main conclusions:

1. Along with the increase of the mining dimensions in the Sotk gold mine and with the increase of the amounts of rock dumps, the organoleptic and chemical indicators in the waters of the Sotk and Masrik Rivers also grow. The quantity of the suspension particles has increased by about 210 %...317.0 % as compared to the same indices obtained for the last 10 years (2010); in the waters of the Sotk River the increase has amounted to 32.1 mg/L, while in those of the Masrik River it makes 13.2 mg/L.

2. Increasing tendencies have also been observed in the mentioned waters regarding the values in the indices of nitrate, sulphate and hydrogenic ions, which are mainly related to the chemical composition of the ore mines, where the alkaline chemicals (Ca, K, Na, Mg, etc.) mainly predominate, and to the intensive agricultural activities carried out in the specific areas, particularly in the riverine land areas, as well as to the application of the single nitrogenous fertilization system and most likely to the development of animal husbandry.

3. The total intensity of the geochemical flow of the heavy metals into the Sotk and Masrik Rivers and their content on the whole considerably fluctuates and varies depending on the exploitation of the Sotk mining site, changes of the volumes of the ore mine, as well as on the feeding of the river and its distance from the mining site.

4. Considering the fact that the waters of the mentioned rivers are also used for the irrigation purposes, and that their constituent heavy metals are endowed with the great ability to accumulate in the soils (deposited), and the last but not the least, their mobility is extremely reduced in the base (alkaline) medium, especially when the environmental reaction (pH) equals to 9, it is recommended that the managerial body of the mining industry should constantly increase the amount of lime (CaO) in the acidic drainage of the mining site provided that the water pH will hold up minimum within the range of 9. At the same time, taking into account that individual heavy metals (selenium, tungsten, vanadium, molybdenum, etc.) are more active in the alkaline medium, it is also necessary to install filters for their refining.

5. The research findings should be used for zoning the neighboring areas of mining organizations according to the degree of heavy metal accretion and for applying the needed technological approaches (phytomelioration, bioremediation, thermal treatment of the harvested yield, preservation, etc.) to reduce the content of heavy metals in the agricultural crops grown in the mentioned areas.

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**ՍՈՐՔ ԵՎ ՄԱՍՐԻԿ ԳԵՏԵՐԻ ՋՐԵՐԻ ԵՎ ՀԱՐԱԿԻՑ ԱԳՐՈՑԵՆՈՋՆԵՐԻ ՎԱՐԵԼԱՀՈՂԵՐԻ
ԷԿՈԼՈԳԱ-ԹՈՒՆԱԲԱՆԱԿԱՆ ՎԻՃԱԿԸ՝ ԿԱՊԱՍԾ ՍՈՐՔ ՀԱՆՔԱՎԱՅՐԻ
ՇԱՀԱԳՈՐԾՄԱՆ ՀԵՏ**

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Բացահայտվել է, որ Սոթք և Մասրիկ գետերի ջրերի օրգանոլեպտիկ և քիմիական ցուցանիշները, հանքարդյունաբերության ծավալների, ինչպես նաև ապարային լցակայանների քանակության ավելացման հետ մեկտեղ, ավելացել են: Կախության մասնիկների քանակությունը մեկ լիտր ջրում, վերջին տասը տարիների համեմատ, ավելացել է 210-317,0 %-ով կամ Սոթքի ջրերում 32,1 մգ/լ-ով, իսկ Մասրիկի ջրերում՝ 13,2 մգ/լ-ով: Համանման փոփոխություններ են նկատվել նաև նիտրատների, սուլֆատների և ջրածնի ցուցիչի արժեքների դեպքում, որոնք պայմանավորված են հիմնականում լեռնային ապարների քիմիական կազմով, որում գերակշռում են հիմնային քիմիական տարրերը (Ca, K, Na, Mg և այլն) և տվյալ տարածքում, մասնավորապես՝ գետերի ափամերձ հատվածներում, ինտենսիվ երկրագործության, ինչպես նաև անասնապահության ըստ ամենայնի զարգացմամբ:

Ուսումնասիրություններով, միևնույն ժամանակ, բացահայտվել է, որ ծանր մետաղների և այլ քիմիական տարրերի պարունակությունը Սոթք և Մասրիկ գետերի ջրերում և հարակից ագրոէկոհամակարգերի հողերում, ինչպես նախորդ 10 տարիներին, այնպես էլ 2019թ.-ին, երկրաքիմիական հոսքի գումարային ինտենսիվությունը զգալիորեն տատանվում և փոխվում է՝ կապված Սոթք հանքավայրի շահագործման և հանքաքարի ծավալների փոփոխության հետ: Ծանր մետաղների շարժունակությունը նվազեցնելու, նշված գետերի ջրերի և վարելահողերի, որոնք ոռոգվում են այդ ջրերով, էկոլոգա-թունաբանական վիճակը բարելավելու համար անհրաժեշտ է հանքավայրի թթվային դրենաժում, մշտապես ավելացնելով կրի CaO քանակությունը այն հաշվով, որ ջրերի միջավայրի ռեակցիան պահպանվի առնվազն 9-ի (рН 9) տիրույթում: Դրա հետ մեկտեղ՝ առանձին ծանր մետաղներ (վոլֆրամ, մոլիբդեն, վանադիում և այլն) առավել ակտիվ են հիմնային միջավայրում, հետևաբար՝ դրանց մաքրման համար անհրաժեշտ է տեղադրել նաև ֆիլտրեր:

Առանցքային բառեր. հանքարդյունաբերություն, Սոթք և Մասրիկ գետերի ջրային համակարգ, օրգանոլեպտիկ հատկություններ, վարելահողեր, ծանր մետաղներ, աղտոտվածություն:

ЭКОЛОГО-ТОКСИКОЛОГИЧЕСКОЕ СОСТОЯНИЕ ВОД РЕК СОТК И МАСРИК И ПРИЛЕГАЮЩИХ ПАХОТНЫХ ЗЕМЕЛЬ АРГОЦЕНОЗОВ, ОБУСЛОВЛЕННОЕ ЭКСПЛУАТАЦИЕЙ СОТКСКОГО РУДНИКА

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Выявлено, что в связи с увеличением объемов горнодобывающей промышленности и количества отвалов горных пород органолептические и химические показатели вод рек Сотк и Масрик увеличиваются. По сравнению с прошлым десятилетием, количество взвешенных частиц в 1 л воды увеличилось на 210...317,0%: в водах Сотка - на 32,1 мг/л, а в водах Масрика - на 13,2 мг/л. Аналогичные изменения наблюдались и в значениях нитратов, сульфатов, водородного индекса, что в основном связано с химическим составом горных пород. В их составе преобладают такие химические элементы, как Са, К, Na, Mg и др. Эта тенденция особенно заметно проявляется вдоль рек, где ведется интенсивное сельское хозяйство, прежде всего животноводство.

Исследования содержания тяжелых металлов и других химических элементов в водах рек Сотк и Масрик и в почвах агроэкосистем также выявили, что, как и в предыдущие 10 лет, суммарная геохимическая интенсивность их потока колеблется в значительных пределах. Это связано с эксплуатацией рудника и изменением объемов добываемой руды. В целях улучшения эколого-токсикологического состояния вод указанных рек и орошаемых ими почв и снижения подвижности тяжелых металлов необходимо постоянное увеличение количества гипса СаО в кислотном дренаже рудника с таким расчетом, чтобы реакция водной среды поддерживалась в пределах не менее 9 (рН 9). В то же время некоторые тяжелые металлы (вольфрам, молибден, ванадий и др.) более активны в щелочной среде, поэтому для очистки вод и почв необходима установка фильтров.

Ключевые слова: горнодобывающая промышленность, водная система рек Сотк и Масрик, органолептические свойства, пахотные земли, тяжелые металлы, загрязнение.