ISSN 1068-3739, Russian Meteorology and Hydrology, 2015, Vol. 40, No. 5, pp. 347–354. Allerton Press, Inc., 2015.
Original Russian Text P.I. Normatov, R. Armstrong, I.Sh. Normatov, N. Narzulloev, 2015, published in Meteorologiya i Gidrologiya, 2015, No. 5, pp. 89–97.

Monitoring Extreme Water Factors and Studying the Anthropogenic Load of Industrial Objects on Water Quality in the Zeravshan River Basin

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Received July 2, 2014

Abstract—Presented are the results of studying the dynamics of changes in the chemical composition of water from the formation zone to the estuary of the Zeravshan River; also the effects are investigated of the sewage of the Anzob ore mining and processing enterprise on the water quality. It is revealed that the concentration of heavy metals in the river water is far from the maximum permissible concentration, i.e., the ore mining and processing enterprise does not affect water composition variations. It is discovered that in the river lower reaches on the territory of the Republic of Uzbekistan the river water is mainly contaminated with drain-collector and municipal waste water. The chemical analysis revealed the presence of cations and anions in the seasonal snow on the glaciers of volcanic origin in the Zeravshan River basin. According to the observational data for the period of 1998–2012, severe floods occur and mudflows causing the appreciable economic damage are formed in Panjakent and Ayni mountain areas in the Zeravshan River basin.

DOI: 10.3103/S106837391505009X

Keywords: The Zeravshan River basin, water quality, anthropogenic load, flood, mudflow, economic damage

1. INTRODUCTION

The water resources in the Aral Sea basin including the territory of five countries are mainly used for irrigation and hydropower engineering. These regions require different regimes of river runoff control. The annual river runoff in winter is essential for the hydropower engineering and the maximum volume of water for irrigation is needed during the vegetation period, i.e., in spring and summer. The diametrically opposite interest of two main water consumers often become a reason for the formation of conflict situations between the countries located in the upper and lower reaches of transboundary rivers in Central Asia [5].

The problems typical of the Syr Darya and Amu Darya transboundary rivers are also typical of the Zeravshan River being the transboundary river between the republics of Uzbekistan and Tajikistan. The essential difference is that the problem of water quality in the Zeravshan River basin is urgent and has gained the intergovernmental significance.

The Zeravshan River (in the upper reaches, the Matcha River) has the length of 877 km, the area of the basin of 17.7 10^3 km^2, and the mean water discharge of 162 m^3/s. It springs from the Zeravshan glacier at the mountain junction between the Turkestan and Zeravshan ranges. The river is mainly fed by glaciers and seasonal snow; therefore, its maximum runoff falls on summer (July and August). During the cold season the Zeravshan River has low water content. On the territory of the Republic of Uzbekistan near Samarkand the Zeravshan River channel divides into two arms: the Ak Darya and Kara Darya rivers. Formerly the Zeravshan River flew into the Amu Darya River. Nowadays it loses its water in the Kyzyl Kum Desert and forms two deltas: the Karakul and Bukhara ones. On the territory of the Republic of Uzbekistan the

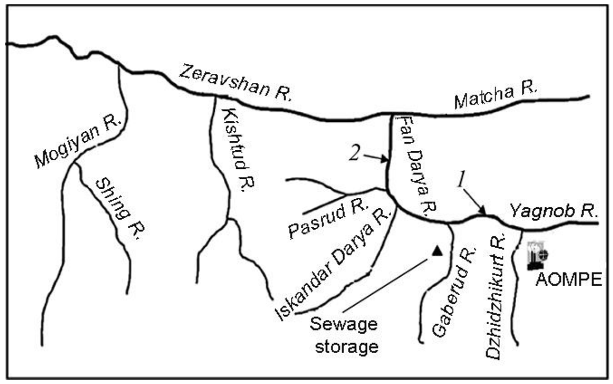

Fig. 1. The scheme of the Zeravshan River and its main tributaries. The numerals are the water sampling points.

Zeravshan River runoff mainly takes place in the following oblasts: 70.2% in the Samarkand region (the irrigated area is 67%), 13.1% (16%) in the Navoi region, 7.4% (8.6%) in the Jizzakh region, and 9.3% (7.8%) in the Qashqadaryo region [1].

The average long-term discharge of the Zeravshan River in the main section is about 140–150 m^3/s. The contribution of the river part located in Tajikistan to the total water intake from the river is 5.23% (253 10^6 of 4834 10^6 m^3). The potential hydropower resource of the Zeravshan River basin is more than 11.8 10^9 kW hour [4].

In spite of so rich energy potential, the Sugd oblast situated in the Zeravshan River basin, has large deficit in electricity equal to 3–4 10^9 (kW hour)/year. This deficit is covered by the import of electricity from Uzbekistan at the world price. Similar situation is observed in agriculture. Only 30 10^3 ha of 132 10^3 ha of the land in the most fertile Istaravshan zone is irrigated. The yearly missed profit here is about 450000 US dollars. Certainly, this situation cannot meet the needs of Tajikistan. This is especially clear if consider the population growth in the republic and the presence of the large areas of fertile uncultivated land in the upper reaches of the Zeravshan River. The scheme of the economic use of the river has to be revised principally so that it consider the current economic situation in Tajikistan and not infringe upon the interests of consumers in its lower reaches on the territory of Uzbekistan. As the analysis demonstrates, such mutual combination of interests can be achieved by means of constructing the cascade of hydropower stations with the river runoff control.

During the period of the USSR water relations among the countries in Central Asia were regulated by the scheme “Integral Use and Protection of Water Resources in the Basins of the Amu Darya and Syr Darya Rivers.” The main objective of this scheme was to determine the real volume of water available for use in the basins of the Amu Darya and Syr Darya rivers as well as to distribute water resources among the republics taking into account the interests of all water consumers. It should be noted that this scheme did not include a number of essential water aspects, namely, the environmental and sanitary and hygienic conditions of rivers and large canals. This was associated with the fact that this scheme was aimed at the provision of agricultural lands with the water used for growing the strategic raw material, namely, the raw cotton. Such approach lead to some serious problems, namely:

—the intensification of environmental disequilibrium;

—the salinization and desertification of lands;

—water quality deterioration;

—the contamination of rivers with pesticides and herbicides;

—increase in water mineralization.

It was revealed before [6] that the Zeravshan River mineralization increases from the upper reaches to the town of Navoi (the Republic of Uzbekistan) from 0.3 to 1.0 g/l and downstream to Bukhara to 2.6 g/l while the bicarbonate composition of water changes to the sulfate one. The dramatic increase in the degree of water mineralization in the area of Bukhara to 2.5–4.0 g/l occurs due to sewage and drain-collector water. According to the results of the atomic-and-absorption analysis, the chemical composition of the

Zeravshan River water varies in wide limits (mg-equiv/%): 15.0–28.0 for HCO_3; 11.74–27.0 for Cl^-; 55.0–69.72 for SO_4^{2} ; 27.0–36.79 for Ca^{2+}; 24.0–45.0 for Mg^{2+}; 28.0–36.82 for Na + K [8].

After the adoption of a number of governmental programs on the development of hydropower resources of the Zeravshan River basin waterways in Tajikistan, the new aspects of the problem of water quality emerged in Uzbekistan. These problems are mainly associated with the contamination of the river with the sewage of the Anzob ore mining and processing enterprise located in the Zeravshan River valley.

The Anzob ore mining and processing enterprise (AOMPE) is the mining enterprise for extracting and concentrating the mercury-antimony ore in the Dzhidzhikurut deposit that has operated since 1954. It is located in the right-bank part of the Dzhidzhikurut River being the left tributary of the Yagnob River (the Yagnob River is the right tributary of the Fan Darya River being one of the main tributaries of the Zeravshan River). In order to prevent the flowing of the enterprise sewage to the Dzhidzhikurut River, the production complex was reconstructed in 1966–1970 and the sewage storage was built in Ravot kishlak situated at the distance of 8–10 km from the enterprise on the bank of the Yagnob River.

2. RESULTS AND DISCUSSION

To determine the degree of the impact of the Anzob ore mining and processing enterprise on the variations of the chemical composition of the Zeravshan River water, in 2010–2012 with the periodicity of three times a month the water samples were taken at points 1 and 2 (Fig. 1) that were located before and after the enterprise sewage storage, respectively. The table presents the summarized results of the chemical analysis of samples taken at points 1 and 2. It is obvious from the comparison of the table data that the Zeravshan River is not polluted with the sewage of the Anzob ore mining and processing enterprise. The content of heavy metals in the river is far from the maximum permissible concentrations. As their content in water samples varies within the limits of the measurement error, these values are not presented in the table. The river is mainly contaminated in its lower reaches on the territory of Uzbekistan with drain-collector, industrial, and municipal waste water in the Samarkand oblast and in Navoi (Fig. 2).

3. THE RISKS ASSOCIATED WITH THE POLLUTION OF GLACIERS AND WITH EMERGENCY SITUATIONS IN THE ZERAVSHAN RIVER BASIN

The study of the accumulating capacity of glaciers with respect to the atmospheric aerosol and fine chemical elements and compounds is important and scientifically valuable. In order to have information on the chemical composition of the water runoff formed from the glaciers in the formation zone, the set of physical and chemical analyses of seasonal snow was carried out in the glaciers Zeravshan, Rossindzh, Dekhadang, Vodif, and Tro (Fig. 3). It is clear from Fig. 3 that the anions SO_4^{2} and Cl^- and the cations Ca^{2+} and Mg^{2+} prevail in the studied glaciers.

The obtained results can be explained in the framework of the concept of the stratospheric aerosol layer consisting of the finest droplets of sulfuric acid. This concept of the aerosol layer formulated in the early 1960s [2] enabled estimating the concentration of stratospheric aerosol by analyzing the ice core from Dronning Maud Land in West Antarctica [9] and working out the method for the quantitative estimation of the power of past volcanic eruptions using the variations of the conductivity and content of the sulfate ion SO_4^{2} in the layers of ice cores [7]. Analyzing the content of heavy metals and their distribution in the fresh solid precipitation in the glaciers of the southern slope of Mount Elbrus, the author of [3] concluded that heavy metals within the composition of microparticles are carried by distant air flows.

The World Conference for Disaster Reduction (WCDR) was organised following the resolution of the United Nations General Assembly and was held in Kobe (Japan) on January 18–22, 2005. It adopted the Hyogo Framework for Action 2005–2015. The conference provided the unique opportunity for propagandizing the strategic and systematic approach to the disaster risk reduction. It revealed the need in and defined the ways for creating the potential of the disaster resilience for countries and communities. In particular, it was noted that the disaster risk is formed when hydrometeorological, geological, and other hazards interact with the vulnerability factors of physical, social, economic, and environmental nature. The reason for the overwhelming majority of disasters is hydrometeorological conditions. The importance of disaster risk reduction and of the potential strengthening in the area of response to disasters is widely known and recognized. However, the risks and hazards of such kind as well as the aspects of disaster risk management and disaster risk reduction are still a great problem. The Hyogo Framework for Action is especially urgent

Results of the chemical analysis of the Zeravshan River water samples

T, C	pH	NO_3	PO_4	HCO_3	SO_4	NO_2	F	Ca	Mg
		mg/l							
Before the sewage storage of the Anzob ore mining and processing enterprise									
12.4	7.62	2.65	0	93.4	36.0	0.004	0.81	38.4	21.64
12.9	8.31	2.54	48.2	56.7	42.4	0	0.52	39.5	25.00
13.1	7.92	3.41	72.4	97.6	55.3	0.001	0.34	37.8	23.32
14.1	8.24	15.04	92.7	105.4	20.8	0	0.27	49.5	20.72
14.8	8.14	11.54	120.0	148.0	22.6	0	0.19	49.2	25.10
15.7	8.24	9.62	112.0	131.4	69.2	0	0.29	48.8	19.98
16.2	8.10	2.73	53.0	159.8	75.0	0.013	1.10	49.6	24.60
16.8	7.98	3.64	61.4	105.9	73.8	0	1.12	47.4	23.78
17.4	6.95	8.61	84.3	74.6	70.6	0.011	0.95	36.8	24.52
18.2	7.89	7.52	136.0	65.4	55.4	0	1.07	38.2	21.32
18.8	7.35	17.36	154.0	56.1	21.0	0	0.60	31.3	19.70
18.4	8.08	14.51	152.0	42.3	24.6	0.014	0.56	35.1	18.79
17.6	8.27	15.06	153.0	31.4	37.8	0.012	0.74	41.7	23.05
16.8	7.95	29.34	4.52	56.7	75.3	0	0.42	44.5	22.45
14.7	8.30	3.74	6.13	26.0	74.8	0.013	0.30	36.7	25.04
14.2	8.40	36.80	121.0	131.2	67.5	0	0.25	41.6	21.64
13.6	8.21	31.28	4.56	101.5	19.3	0.011	0.18	33.8	19.58
14.2	7.96	27.68	102.0	96.4	21.2	0.009	0.11	49.2	17.64
15.3	8.17	11.74	147.0	32.7	47.3	0	0.01	43.8	16.54
15.9	8.30	10.95	110.0	56.8	59.3	0.001	0.13	37,4	24.74
16.4	8.19	9.74	87.4	64.5	66.7	0.007	0.26	39.6	22.53
16.8	8.29	8.04	127.0	127.4	74.9	0.013	0.19	40.5	25.20
17.3	8.21	3.34	149.0	131.2	38.3	0.012	0.21	42.7	23.30
17.1	8.34	19.30	132.0	47.4	42.8	0.009	0.22	46.4	22.50
After the sewage storage of the Anzob ore mining and processing enterprise									
12.5	7.62	2.82	4.46	94.6	41.0	0.006	0.77	39.1	20.72
13.1	8.31	2.35	54.28	61.3	39.8	0.002	0.62	36.5	23.43
13.2	7.92	3.13	69.41	74.5	57.2	0	0.26	38.2	13.64
14.3	8.24	14.56	94.38	111.3	24.6	0	0.31	46.8	16.73
15.0	8.14	9.96	124.35	136.0	24.5	0	0.24	45.3	17.41
15.4	2.24	11.2	113.22	128.6	71.1	0.013	0.19	47.3	21.83
16.3	8.10	4.36	57.43	158.3	78.4	0	0.29	44.6	23.82
17.0	7.98	5.18	63.41	115.7	38.3	0	1.02	18.2	22.65
17.6	6.95	9.16	79.38	79.1	67.4	0.012	1.15	35.6	23.74
18.1	7.89	6.62	142.40	68.8	51.6	0.001	1.12	36.1	13.91
19.0	7.35	21.45	155.62	62.5	19.9	0	0.69	29.6	17.81
18.5	8.08	14.51	148.12	45.34	23.9	0	0.61	33.8	19.92
17.9	8.27	17.31	155.20	33.24	41.8	0.009	0.79	40.3	22.83
17.1	7.95	32.23	6.22	53.4	69.6	0	0.58	42.4	21.75
14.9	8.30	6.12	8.78	31.75	75.0	0	0.28	35.8	26.31
14.1	8.40	38.54	122.14	130.7	66.3	0	0.18	43.7	23.43
13.7	8.21	29.18	7.34	102.1	22.6	0	0.21	36.7	21.54
14.4	7.96	30.72	103.15	97.4	25.5	0	0.17	49.8	13.71
15.5	8.17	12.1	146.60	33.0	48.1	0.009	0.01	42.3	16.92
16.2	8.30	11.17	112.00	52.9	56.9	0.0014	0.14	38.6	25.13
16.6	8.19	10.64	88.10	62.5	71.1	0.008	0.28	39.9	23.09
17.0	8.29	7.73	129.20	134.6	75.0	0	0.23	41.3	26.11
17.4	8.21	4.21	151.30	97.8	33.5	0.011	0.20	43.7	24.10
17.0	8.34	22.42	131.10	49.3	40.8	0.001	0.24	47.2	21.90

Table. (Contd.)

Al	Fe	Mn	Cu	Cr(VI)	Zn	Na + K	SiO_2	Si
mg/l								
Before the sewage storage of the Anzob ore mining and processing enterprise								
0	0.11	0	0	0	0	51.24	3.92	1.74
0.01	0.13	0	0.09	0	0.07	50.94	4.01	1.82
0	0.24	0	0.01	0.024	0.04	48.41	3.86	1.91
0.03	0.31	0.017	0	0.032	0.06	52.10	3.24	1.68
0.07	0.16	0.030	0.08	0	0.01	50.76	3.96	1.79
0.04	0.24	0.006	0.09	0	0.02	48.76	4.12	1.86
0	0.27	0	0.11	0	0.03	50.20	4.00	1.95
0.042	0.19	0	0.08	0.020	0.04	51.62	4.20	1.92
0.051	0.21	0.004	0.078	0.018	0.09	50.96	4.40	1.51
0.037	0.17	0	0.62	0.021	0.08	52.01	3.46	1.62
0.08	0.13	0.006	0.013	0	0.06	52.41	3.30	1.54
0.06	0.14	0	0.064	0.016	0	48.68	4.34	1.71
0.072	0.08	0.054	0.057	0.030	0.05	52.12	4.61	1.68
0.025	0.11	0.039	0	0	0.03	49.21	4.84	1.73
0.03	0.09	0	0	0.040	8	51.68	4.90	1.89
0.015	0.12	0.024	0	0.017	0	50.92	3.84	1.47
0.065	0.06	0.017	0	0.027	0	48.34	2.51	1.91
0.053	0.11	0.032	0.075	0.030	0.020	32.86	4.52	1.84
0	0.10	0.037	0.064	0	0.019	47.64	3.27	1.64
0.027	0.18	0.032	0	0.009	0.014	42.65	4.59	1.51
0.019	0.24	0.005	0.059	0.014	0.013	37.62	3.84	1.71
0.031	0.30	0.044	0.043	0.025	0.020	50.30	3.32	1.69
0.029	0.22	0.047	0.073	0.031	0.015	49.70	2.87	1.89
0.038	0.16	0.032	0.054	0.035	0.025	48.80	3.44	1.32
After the sewage storage of the Anzob ore mining and processing enterprise								
0	0.13	0.011	0.003	0	0.012	52.31	4.01	1.97
0	0.15	0.01	0.008	0	0.05	51.43	4.27	1.89
0.015	0.27	0	0.011	0	0.0045	49.34	4.12	2.01
0.032	0.19	0	0.01	0.028	0.0053	51.87	3.43	1.74
0.041	0.17	0	0.09	0.015	0.009	50.90	3.86	1.83
0.028	0.26	0.009	0.1	0.01	0.022	49.86	3.93	1.92
0	0.25	0.004	0.032	0.009	0.032	52.03	3.95	1.97
0.036	0.22	0.001	0.01	0.019	0.041	50.93	4.15	1.93
0.04	0.24	0.008	0.078	0.02	0.007	49.74	4.44	1.48
0.039	0.16	0.001	0.074	0.022	0.083	51.73	3.49	1.56
0.083	0.14	0.042	0.015	0.017	0.071	51.88	3.35	1.55
0.071	0.13	0.041	0.071	0.019	0.007	46.64	4.37	1.73
0.076	0.09	0	0.062	0.033	0.054	50.14	4.65	1.71
0.029	0.15	0	0.013	0.012	0.034	48.73	4.91	1.75
0.031	0.11	0.021	0.01	0.037	0.013	50.78	4.88	1.92
0.019	0.10	0.034	0	0.02	0	49.37	3.79	1.39
0.044	0.10	0.019	0.01	0.031	0	49.68	2.56	1.89
0.056	0.13	0.034	0.081	0.029	0.019	35.32	4.37	1.82
0.021	0.12	0.032	0.069	0.014	0.017	45.56	3.12	1.61
0.03	0.22	0.036	0	0.01	0.015	43.73	4.17	1.49
0.02	0.26	0.037	0.061	0.015	0.014	39.02	3.92	1.73
0.029	0.29	0.005	0.046	0.029	0.021	49.93	3.34	1.70
0.031	0.21	0.049	0.078	0.034	0.019	48.89	2.90	1.87
0.054	0.18	0.034	0.06	0.037	0.029	49.02	3.41	1.34

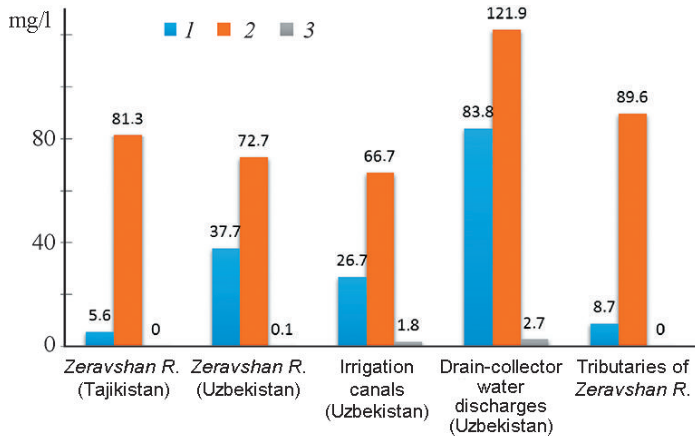

Fig. 2. The concentration of (*1*) nitrates NO_3, (*2*) phosphates PO_4, and (*3*) ammonium NH_4 in the Zeravshan River, its tributaries, and irrigation canals and drain-collector waters on the territory of Uzbekistan.

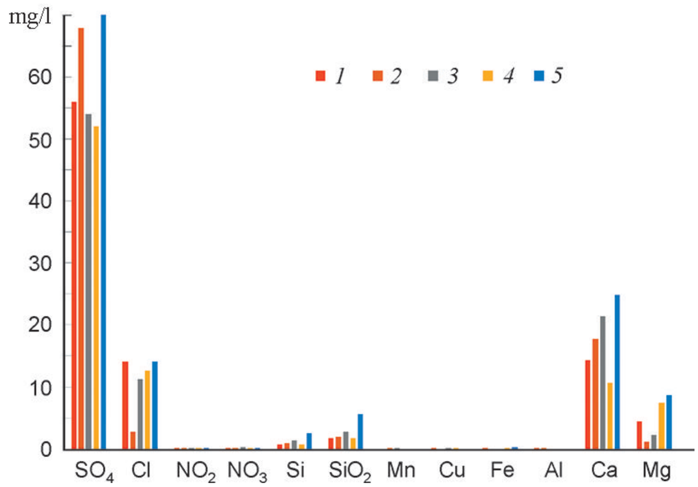

Fig. 3. The concentration of chemical elements in the seasonal snow in the glaciers of the Zeravshan River basin. (*1*) Zeravshan; (*2*) Rossindzh; (*3*) Dekhadang; (*4*) Vodif; (*5*) Tro.

for mountain countries, there the effects of meteorological and hydrological cataclysms on the different aspects of the human life are more pronounced [10].

In the Zeravshan River basin in the Republic of Tajikistan, emergency situations associated with the water factor, namely, with floods, mudflows, and snow avalanches are more often observed as compared to other regions. In the river basin emergencies are observed more than 150 times per year on average (about 7% of the total number for the whole territory of the republic). Every year the majority of the basin population, namely, the population of the Ayni and Panjakent regions suffers great economic damage and sometimes even has human losses.

Floods and mudflows were registered in the Ayni and Panjakent regions of the Zeravshan River every year over the period of observations and registration of emergency situations related to the water factor from 1998 to 2012. According to the data of the Committee for Emergency Situations and Civil Defense affiliated to the Government of the Republic of Tajikistan, the flood of the most appreciable scale in Panjakent area was registered in 2010; it caused the total economic damage of 4.66×10^6 USD. The severe flood in the Ayni region was observed in 2002, the economic damage was more than 3×10^6 USD (Fig. 4a).

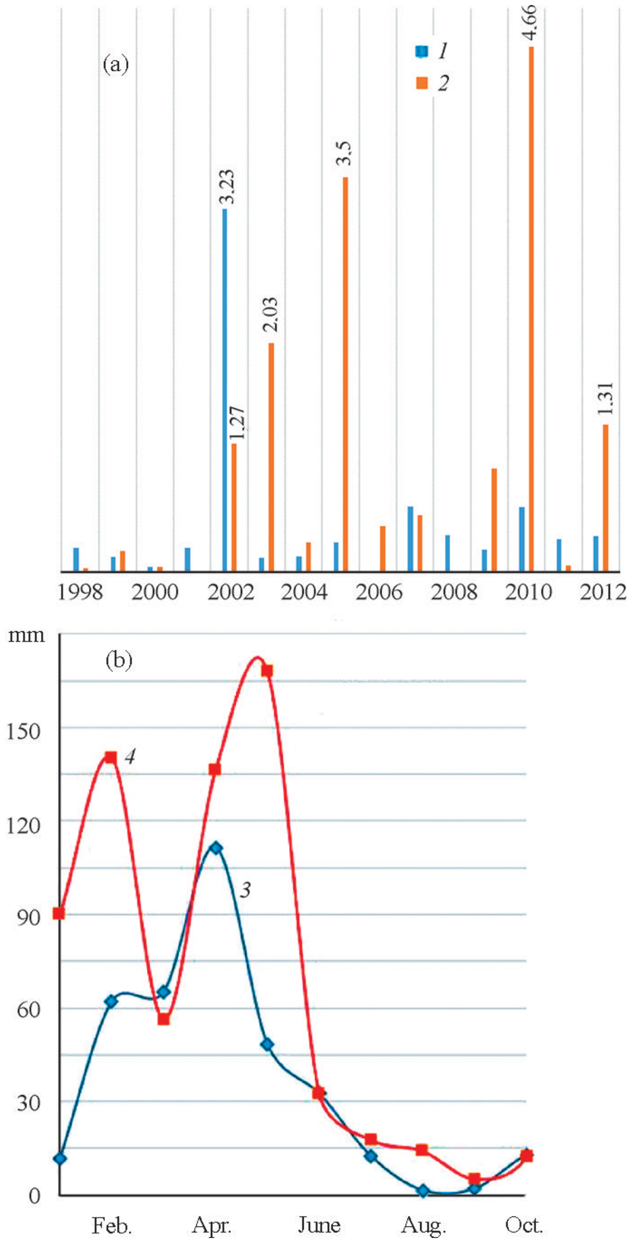

Fig. 4. (a) Economic damage (in millions of USD) caused by floods and mudflows in Ayni (*1*) and Panjakent (*2*) mountain areas situated in the Zeravshan River basin and (b) the seasonal distribution of precipitation in the basin. (*3*) Ayni, 2002; (*4*) Panjakent, 2010.

The weather stations installed in the mentioned areas registered heavy precipitation in the form of rain that is indicated by the seasonal distribution of the amount of precipitation in these mountain areas in the respective years presented in Fig. 4b.

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