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ASSESSMENT OF THE CONTRIBUTION OF METEOROLOGICAL FACTORS TO THE FORMATION OF SUSPENDED SEDIMENTS IN THE MOUNTAIN RIVERS OF UZBEKISTAN

Annotation. *The article discusses the issues of studying the flow of suspended sediment and assessing the intensity of soil washout from their mountain river basins in Uzbekistan and adjacent territories. Data on the runoff of suspended sediment from rivers were used as source materials. The article also evaluates the contributions of atmospheric precipitation of different seasons and air temperature to the formation of suspended sediment runoff in mountain rivers. Calculation nomograms are proposed for quantitative assessment of suspended sediment runoff in rivers, built on the basis of normalized regression equations characterizing the relationship between suspended sediment runoff and hydrometeorological factors. The quantitative indicators of hydrological quantities characterizing the intensity of soil washout from river basins have been clarified by testing the calculated nomograms. the average long-term values of quantitative indicators of suspended sediment runoff in rivers have been determined, that is, the norms of sediment volume, flushing modulus, erosion meter, and others.*

Keywords: river, high-mountain basin, glaciation, soil erosion, suspended sediment flow, statistical evaluation, nomogram, forecast, washout intensity.

Introduction. As a result of global climate change occurring on a global scale, there is an increase in the area of arid territories and an increase in the intensity of soil erosion. As stated in studies carried out by foreign experts, "... with population growth, the potential of agricultural production simultaneously decreases, this is facilitated by a decrease in soil fertility as a result of water erosion and inefficient use of agro-climatic resources, primarily the reason for this is the incorrect specialization of territories by agricultural sectors[1]. This situation indicates the need to study the mechanism of formation of suspended sediment runoff in mountain rivers and improve methods for assessing the intensity of soil washout from the surface of river basins.

Priority attention in the world is given to research in this area, in particular, water erosion and the study of the features of the formation of suspended river runoff, and the improvement of methods for their assessment. Therefore, today the improvement of methods for assessing the intensity of soil washout from the surface of mountain river catchments and, on this basis, the design of irrigation systems, hydraulic structures and other utilities, their construction and efficient operation, in the future the phased development of land-water and water-energy resources of mountain territories of arid countries, as well as the development of long-term plans for their optimal use are pressing issues.

The republic is implementing a number of activities aimed at developing agricultural production, rational use of the country's land and water resources, effective use of water and hydropower resources of small rivers and watercourses, construction of small reservoirs, and significant positive results have been achieved. The Action Strategy for five priority areas of development of the Republic of Uzbekistan identifies as important the tasks of "improving the reclamation conditions of irrigated lands, introducing modern technologies for

[1] An Introduction to Water Erosion Control, December 2017.

saving water and water resources in the field of agricultural production"[2]. In this regard, in particular, scientific research aimed at studying the hydrological regime and the flow of suspended sediment of mountain rivers, and improving methods for calculating their hydrological characteristics, are of great importance.

The process of water erosion occurring in river basins and the formation of their product - the runoff of suspended sediment from rivers and the issues of their quantitative assessment are the subject of research by many foreign scientists. In particular, these issues are considered in the works of scientists of the former Union and the current CIS - D.I. Abramovich, B.V. Polyakov, G.I. Shamov, G.V. Lopatin, N.I. Makkaveev, A.V. Karaushev, G.N.Khmaladze, M.N.Zaslavsky, K.S.Kabanova, R.S.Chalova, G.I.Shvebs, A.P.Dedkova, V.I.Mozzherina, scientists from far abroad - R.E. Horton, H.H.Bennett, A.Barat, N.L.Coleman, J.M.Jansen, R.B.Painter, V.A.Vanoni, W.D.Ellison, J.N.Holeman, W.H.Wisehmeier and others. These works examine methods for quantitative assessment of water erosion in river basins and scientific approaches aimed at studying the influence of various physical and geographical factors on this process, and develop criteria for classifying river basins according to the intensity of water erosion [4.6.8.13].

In Uzbekistan, the first monographic studies in this area were carried out by V.L. Schultz, O.P. Sheglova and others. Subsequently, these issues were studied by A.A.Khanazarov, Kh.M.Makhsudov, Yu.N.Ivanov, A.R.Rasulov, S.R.Saidova, Z.S.Sirlibaeva, A.N.Nigmatov, F.Kh.Khikmatov, Kh.K.Tashmetov, D.P.Aitbaev and others. The works of these scientists are devoted mainly to the study of the process of water erosion and its product - the runoff of suspended sediment in rivers, the features of its formation, the influence of various physical and geographical factors, in particular, the study of

[2] Decree of the President of the Republic of Uzbekistan No. PF-4947 of February 7, 2017 "On the Action Strategy for the further development of the Republic of Uzbekistan"

the role of climatic factors and, ultimately, the rational use of land and water resources [2.4.6.8.13].

However, almost all of the above works focus on studying the suspended sediment runoff of large rivers abroad, the former Soviet Union or Central Asia and assessing the intensity of water erosion occurring in their basins. These works do not consider rivers that form in Uzbekistan and adjacent territories. This study is devoted to a more thorough and wide-ranging study of the problem associated with the formation of suspended sediment runoff and the intensity of soil loss using the example of mountain rivers of Uzbekistan, based on new hydrological information. It is in these aspects that it differs from the above works.

The purpose of the study is to identify the peculiarities of the formation of suspended sediment runoff in mountain rivers of Uzbekistan and to improve methods for quantitatively assessing the intensity of soil washout from the surface of their basins.

Research objectives: to investigate the process of formation of suspended sediment runoff in rivers depending on hydrological and meteorological factors; determination of average long-term values, that is, norms of hydrological indicators - flow rates and volumes of suspended sediment runoff, washout module, washout layer and others, characterizing the intensity of soil washout from the surface of river basins; improvement of existing methods for quantitative assessment of the intensity of soil washout from river basins, taking into account the influence of meteorological factors on them; identification of features of the distribution of the intensity of soil washout from river basins in altitudinal zones; mapping the intensity of soil washout from river basins, taking into account the peculiarities of their changes according to altitudinal zones.

The object of the study is the mountain rivers of Uzbekistan and adjacent territories and the flow of suspended sediment from these rivers.

The subject of the study is to identify the features of the process of soil

washout from the surface of mountain river basins and the formation of suspended sediment runoff, as well as the improvement of methods for quantitative assessment of hydrological quantities characterizing these processes.

Research methods. The work used special methods of hydrological calculations and forecasts, hydrological analogy, geographical generalization, statistical mathematics, in particular, an objective method of leveling and normalizing correlations, a cartographic method and others.

Results and Discussion. Based on the main goal of the work, a description of the natural conditions of the mountain river basins of Uzbekistan is given from the point of view of the formation of suspended sediment runoff. In this direction, the main attention is paid to the study of suspended sediments of the rivers of the Chirchik, Akhangaran, Sanzar, Zaaminsu, Zeravshan (within Uzbekistan), Kashkadarya and Surkhandarya basins. Therefore, in each river basin under study, the peculiarities of its physical and geographical conditions were studied.

Particular attention is paid to describing the features of changes in altitudinal zones of meteorological quantities - precipitation and air temperature, which have a major impact on the wash-off of soils from river basins and on the formation of suspended sediments in rivers.

For this purpose, using the example of the Chirchik River basin, based on the materials of meteorological observation points carried out in their basins, changes in precipitation and air temperature with the altitude of the area are considered (Figure 1 and 2).

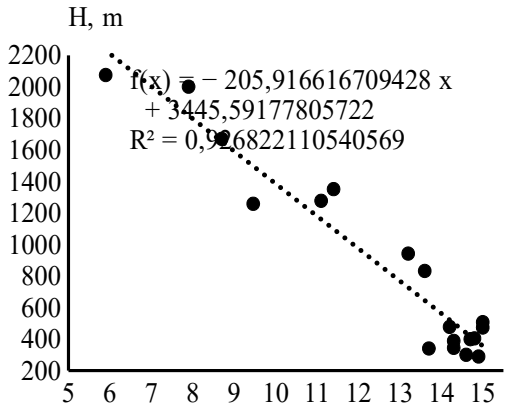

Fig.1. Changes in air temperature with height in the Chirchik-Akhangaran basin

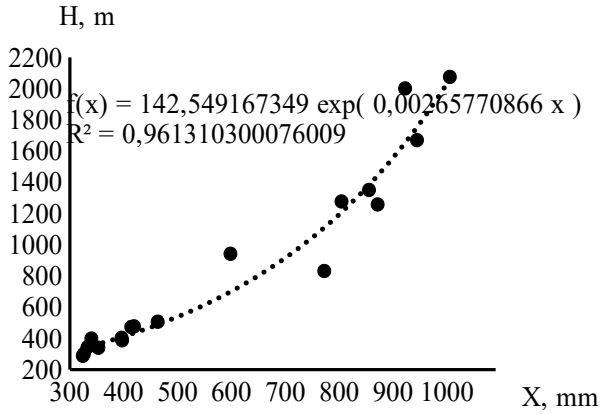

Fig.2. Changes in atmospheric precipitation with altitude in the Chirchik-Akhangaran basin

In the work, based on the corresponding analysis, 71 hydrological observation points were selected as reference points. The distribution of these points across river basins is different. Of these, 32 points are located in the Syrdarya basin, and 39 points are in the Amu Darya basin.

The coefficients of variability of suspended sediment runoff and water discharge (C_{VR} and C_{VQ}) were statistically assessed, and their relationship was studied (Fig. 3). The connections between suspended sediment runoff and water flow rates are considered using the example of all river basins selected as the object of study. Based on observation data at hydrological posts of the rivers under study, paired correlation coefficients were calculated, characterizing the closeness of the relationship between the average annual flow of suspended sediment and water flows, and an analysis of the results obtained was carried out. For example, calculated for the Chatkal River based on observation data at the hydrological station at the mouth of the Khudaidadsay River, the value of the pair correlation coefficient, expressing the closeness of the relationship of the type R=f(Q), is equal to 0.876 and its error was ±0.022 (Fig. 4).

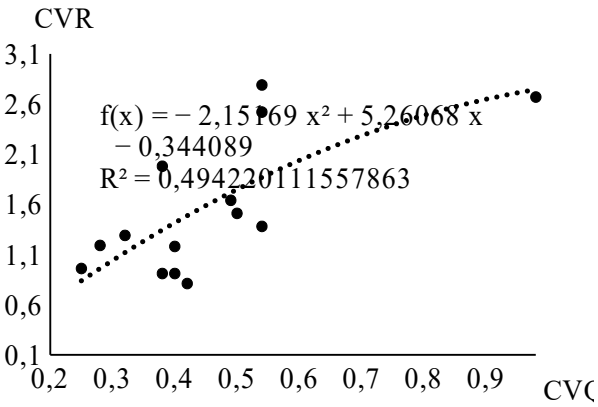

Fig.3. Relationship between coefficients of variation of annual suspended sediment runoff (C_{VR}) and water discharge (C_{VQ}) (Kashkadarya basin)

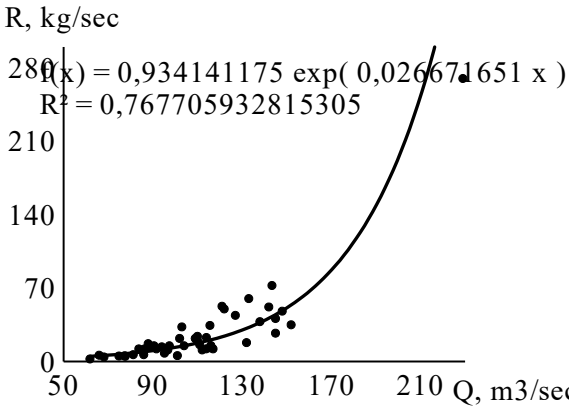

Fig.4. Relationship between suspended sediment runoff (R) and water flow (Q), Chatkal - Khudaydadsay

The values of paired correlation coefficients, characterizing the close relationship between the runoff of suspended sediment and river water flows, in all studied basins, vary within the range of 0.600 ÷ 0.978, in 70% of cases their value was greater than 0.75 (Table 1).

Table 1

Intervals of changes in pair correlation coefficients of suspended sediment runoff and water flow rates

№	River basin	Number of observation points, N	Change intervals	
			R_{min}	R_{mak}
1	Chirchik	13	0.669	0.900
2	Akhangaran	12	0.616	0.971
3	Sanzar-Zaminsu	7	0.733	0.931
4	Zeravshan	8	0.684	0.858
5	Kashkadarya	15	0.600	0.978
6	Surkhandarya	16	0.610	0.892
	Total	71		

The intensity of erosion processes arising from the melt water of eternal snow and glaciers in the highlands is mainly determined by the magnitude of positive air temperatures. When choosing the calculation period for air temperature, we took into account intra-annual changes in the flow of suspended sediment on the rivers of Uzbekistan. As a result, their average values observed at meteorological stations during the warm half of the year, that

is, the months April-September, were used as an index of the air temperature regime.

Calculations were performed using the objective method of alignment and normalization of correlations proposed by G.A. Alekseev.

Paired correlation coefficients were calculated between the discharge of suspended sediment in the mountain rivers of Uzbekistan and climatic factors, that is, precipitation in the winter (X_w) and summer (X_s) seasons and average summer air temperature (t_s). The calculated values of pair correlation coefficients (r_{01}, r_{02}, r_{03}, r_{12}, r_{13} and r_{23}) were analyzed and the limits of their changes were assessed (Table 2).

Table 2

Statistical indicators of the relationship between suspended sediment runoff and meteorological factors

No.	River basin	N	Change intervals		
			r_{01}	r_{02}	r_{03}
1	Chirchik	11	0,124÷0,674	0,133÷0,523	-0,457÷0,182
2	Akhangaran	9	-0,284÷0,447	0,510÷0,769	-0,599÷-0,068
3	Sanzar-Zaminsu	6	-0,140÷0,415	0,060÷0,414	-0,470÷0,380
4	Zeravshan	7	-0,099÷0,529	0,170÷0,456	-0,634÷ -0,072
5	Kashkadarya	7	0,272÷0,480	0,155÷0,517	-0,609÷ -0,166
6	Surkhandarya	13	-0,160÷0,785	-0,030÷0,614	-0,516÷ -0,049

Note: *r_{01}, r_{02}, r_{03} are paired correlation coefficients characterizing the relationship between suspended sediment flow rates and, accordingly, winter and summer precipitation and summer air temperature.*

In all studied river basins, pairwise correlation coefficients between suspended sediment runoff and winter and summer precipitation were obtained with positive values, which vary, respectively, within the range of 0.124÷0.674 and 0.133÷0.523. On rivers of the snow-rain type of feeding, the connection between the runoff of suspended sediment and summer precipitation turned out to be closer, but on rivers of the snow-type feeding type, the opposite turned out to be the case, that is, the connection with winter precipitation turned out to be closer.

In the work, regression coefficients (α_{01}, α_{02}, α_{03}) were calculated for all river basins studied. Based on these values and the values of paired correlation coefficients, the total correlation coefficients (r0) were calculated, allowing one to evaluate the accuracy of the equations of normalized values (Table 3).

Table 3

Limits of changes in regression coefficients and total correlation coefficients

No.	River basin	N	Change intervals			
			α_{01}	α_{02}	α_{03}	r_0
1	Chirchik	11	0,064÷0,620	0,049÷0,481	-0,411÷0,144	0,50÷0,74
2	Akhangaran	9	-0,169÷0,382	0,400÷0,885	-0,307÷0,671	0,48÷0,81
3	Sanzar-Zaminsu	6	0,230÷0,425	-0,045÷0,574	-0,448÷0,474	0,50÷0,59
4	Zeravshan	7	-0,272÷0,507	0,146÷0,389	-0,059÷-0,535	0,44÷0,68
5	Kashkadarya	7	0,123÷0,389	0,009÷0,34	-0,054÷-0,460	0,48÷0,66
6	Surkhandarya	13	-0,199÷0,745	-0,171÷0,557	-0,028÷-0,510	0,50÷0,84

Note: *N – number of hydrological observation posts; α_{01}, α_{02} and α_{03} – regression coefficients; r_0 – total correlation coefficient.*

At 11 hydrological stations in the Chirchik basin, the values of the total correlation coefficient, characterizing the closeness of the relationship between the observed values of suspended sediment runoff and meteorological factors (X_w, X_s, t_s) along the rivers of the basin, are distributed as follows: on 3 rivers the values of $r_0 = 0.50 \div 0.60$ were obtained, and on the remaining rivers their values vary in the range $0.71 \div 0.74$. On the rivers of the Akhangaran basin, the total correlation coefficients, except for the Dukantsai (Dukant) River, whose total coefficient is $r_0 = 0.48$, vary within the range of $0.65 \div 0.81$.

The rivers under study, according to the classification of O.P. Shcheglova by type of nutrition, are divided into corresponding groups. For each type of river feeding, the shares of the average values of the contributions of summer air temperature, summer and winter precipitation involved in the formation of suspended sediment runoff were determined (Fig. 5).

The contributions of summer and winter precipitation to the formation of suspended sediment runoff, according to the sources of river feeding, differ from

each other. For example, for the rivers of the Chirchik basin, the contributions of winter precipitation, according to the increase in the average height of the river basins, also increase. If, for the relatively low-lying basins of the Ugam and Nauvalisai rivers, the contribution of winter precipitation is 50-55%, then for the Pskem River and its tributaries, the average height of the basins of which is relatively higher, the contribution of winter precipitation is 65-75%. Contributions of summer precipitation on these rivers, on the contrary, decrease (Fig. 5).

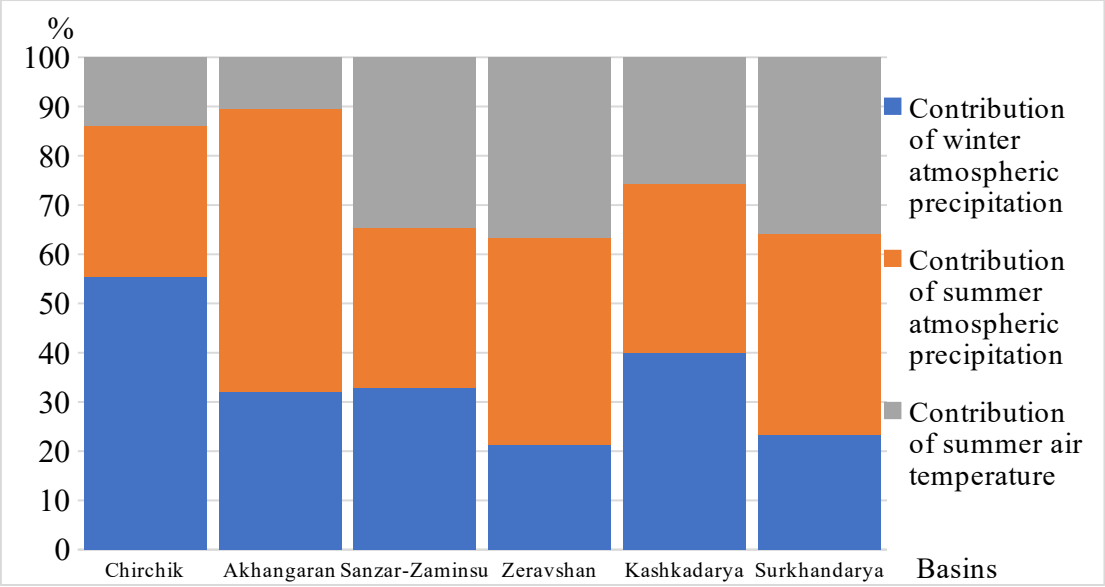

Fig.5. Contribution of meteorological factors to the formation of suspended sediment runoff

Conclusions:

1. The features of the natural conditions of the mountain river basins of Uzbekistan have been studied from the point of view of the formation of suspended sediment runoff. Hydrological knowledge of the territory was analyzed from more than 200 hydrological stations, and meteorological knowledge was highlighted based on the analysis of meteorological data from about 100 meteorological observation points. Based on the accepted criteria, 71 observation points were accepted as design hydrological posts. The drainage area at these stations varies in the range of 15.6÷10900 km^2, and the average

height of the catchment areas varies in the range of 910÷3140 meters.

2. The coefficients of variation of suspended sediment runoff and river water discharges were calculated and the relationship between these coefficients was statistically assessed. Changes in the correlation coefficients characterizing these connections are located in the range of 0.68÷0.98. A statistical indicator of the closeness of connections of the form R=f(Q), i.e. the correlation coefficient for all river basins fulfills the condition ≥0.50, thereby meeting the criteria set in hydrological calculations.

3. The relationships between the average annual values of suspended sediment in rivers and meteorological factors, that is, winter and summer precipitation, were studied. In all studied river basins, pairwise correlation coefficients expressing the closeness of the connection were positive in all cases and varied, respectively, within the range of 0.124÷0.674 and 0.133÷0.523. The highest values of these coefficients turned out to be for rivers of snow-rain and snow feeding types.

4. Based on the regression coefficients (α_{01}, α_{02}, α_{03}) and paired correlation coefficients (r_{01}, r_{02}, r_{03}), the total correlation coefficients (r_0) were calculated, making it possible to evaluate the accuracy of the normalized regression equation. If on 3 rivers out of 11 located in the Chirchik River basin, the total correlation coefficient varied in the range from 0.50 to 0.60, then in the remaining rivers their value varies in the range 0.71÷0.74. The values of the total correlation coefficient for almost all rivers of the Akhangaran basin (except for Dukantsai, where r_0 = 0.48) vary within the range of 0.65÷0.81. The results of these calculations will make it possible to use the normalized regression equations obtained in the work in special hydrological calculations.

5. The rivers under study are divided into groups according to types of nutrition, according to the classification of O.P. Shcheglova. For each type of river feeding, the average values of the contributions of summer air temperature, summer and winter precipitation to the formation of suspended sediment runoff

were determined. Quantitative values of hydrological quantities have been determined, characterizing the intensity of washout from the surface of river basins for each type of river feeding, for years characteristic of water content. In the Zeravshan river basins, the contributions of summer air temperatures averaged 35%, summer precipitation 40%, and winter precipitation amounted to about 25%. The values of these relative values, that is, the contributions of winter and summer precipitation, increase near rivers of snow and snow-rain types of feeding.

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