Estimating determinative factors of reservoir sedimentation processes

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***Abstract*—the article provides discussion about sediment transportation and its velocity, also main attention given to analyse of hydrometeorological parameters and sediment regime of The Surkhandarya River which main source of South Surkhan water reservoir. In this research we used materials from exploitation and field studies for the water reservoir of South Surkhan. Final estimations demonstrate that at the Shurchi hydrological station of the Surkhandarya River, the average sediment concentration is 2.02 g/l or 2 kg/m3. River sediments were determined in volume ratios and in masses. Module of erosion is 509 $\frac{\text{tons}}{\text{км}^2 \cdot \text{year}}$, the layer of erosion 0,443 mm/year erosion meter is equals to 2257 years.**

Keywords—Water erosion, bank erosion, gross erosion, sedimentation module, erosion layer, erosion meter, water reservoir

I. INTRODUCTION

It is well known, agricultural production in Uzbekistan is based on irrigated agriculture. That is the main reason for building many reservoirs to prevent water shortages during the vegetation period. There are about 10 water reservoirs in the Surkhandarya region. Estimating the effects of potential sediment accumulation in reservoirs is important element in the of a dam project. Sediment accumulation in a reservoir may reduce the useful storage volume for water in this reservoir, change the water quality near the dam, and increase flooding level upstream of the dam due to sediment aggradation [5]. One of the key questions is to study the rate of water erosion and the amount of solid runoff for the long-term use of these reservoirs.

The main purpose of this article was to investigate the rate and intensity of water erosion and the degree of sedimentation in the Surkhandarya reservoir.

River sediments (bed load sediments and suspended sediments) are formed as a result of the destruction of the earth's surface under the influence of water movement and erosion of the river system, in other words, as a result of the activity of water.

The process of surface erosion is the main source of river sediment. It is divided into mountain slope erosion and river erosion. The surface erosion process begins when raindrops impact the ground and detach soil particles by splash [5]. Destruction of slopes is the leaching of soil from mountain cliffs under the influence of surface runoff streaming to the river bed, which is characterized by surface erosion and deep erosion. Without surface runoff, the soil erosion losses from nearly level fields are very small. Surface erosion rates largely depend on unit discharge and surface slope [5].

Deep washing leads to the formation of a ravine when it passes through erosion and creep. Such caves are found along river banks and near watersheds. In general, the formation of a ravine is closely related to natural conditions, including the composition of the rock, which forms the surface of the earth. This process is also the result of landslides and displacements of the earth's surface [1].

II. METHODS OF THE RESEARCH

In this research we used materials from exploitation and field studies on the water reservoir of South Surkhan. For calculations, mathematical and statistical methods were applied, and then comparisons were carried out between field data with calculated measurements for chosen hydrologic stations.

III. RESULTS AND DISCUSSIONS

Studies show that the bulk of river sediments are formed by erosion of the surface soil layers. In addition, the intensity of water erosion and the formation of a river bed depend on many other factors [8]. Depending on the conditions of their impact, the main natural factors are as follows: climatic conditions of the terrain, topography, lithological composition of the surface covering the rocks, geological structure, type and condition of soil, vegetation cover, density of vegetation cover, etc.

Water erosion can be accelerated by human activities in various ways; hence it is called anthropogenic erosion. Furthermore, chemical degradation occurs, which is formed under the influence of surface and groundwater and air temperature. This process is speeded up in hot and humid climates. Limestones and dolomites easily pass into chemical decay. A karst phenomenon is the result of chemical erosion. Each of the above factors has a peculiar effect on how surface water erosion happens.

The above processes are the main factors in the formation of river sediments. The object of research in the article is the Surkhandarya River - one of the muddy rivers of Uzbekistan, which flows into the Surkhandarya water reservoir. In the upper reaches (near Korovultepa river), the average sedimentation rate of the river is 0.908 kg / m3, and

in the village of Molguzar - 2.90 kg / m3. This means that the turbidity of the water in the Molguzar River is more than three times higher than in Korovultepa. It is obvious that, as in most rivers of Central Asia, in Surkhandarya, the amount of sediment increases with the downstream river. By character of river sediment, the Surkhandarya River not significantly differs from the Amu Darya River. The average long-term flow rate of sediment movement in the river is 62.8 kg / s, or 1978 thousand tons per year, near Korovultepa, and 193 kg / s, or 6080 thousand tons per year, near Molguzar river [1, 2].

The Surkhandarya River - has a type of glacial and snow nourishment according to the classification of V.L. Schultz [6]. Due to the fact that the South Surkhan reservoir is located in the riverbed of the Surkhandarya river, various deposits of sediment from the river to the reservoir occur during the year. Taking into account the mudflows in the Surkhandarya basin and its tributaries in April-June, therefore, during this period, the main siltation in the reservoir occurs. Table 1 shows changes in sediment movement fluctuations in the Surkhandarya River in long-term perspective.

1- table

Changes in sediment movement long-term fluctuations in the Surkhandarya River (hydrologic station Shurchi, 1987-2016)

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Sed., kg/m³	0,49	0,59	1,81	3,84	4,84	4,64	2,02	1,07	0,21	0,32	0,52	0,49	2,86
dis	24	32	158	592	1011	915	238	52	6	13	25	25	258

When estimating the sedimentation intensity of river sediments, it is important to understand the fractional composition of the river stream. The fractional composition of suspended sediments in the Surkhandarya river is presented in table 2, and the fractional structure of sedimentation accumulation of the bottom of the reservoir is presented in the table 3.

2- table

Fractional structure of suspended sediment of Surkhandarya River, in %

Diameter of particle, mm	0,25 and more	0,25÷0,10	0,10÷0,05	0,05÷0,01	0,01 and less
April-Sep.	3,2	11,6	18,3	24,6	42,3
October-March	5,7	28,9	14,8	17,1	38,5
Average annual	4,5	17,7	16,6	20,8	40,4

Comparing the data of the above and subsequent tables, the sizes of the sedimentation particles of the river flow varies greatly. For example, the diameter of suspended sediment is 0.25 mm or less, and the sediment particle at the bottom of the reservoir makes up several centimeters [9].

3- table

Fractional structure of Surkhandarya River sedimentation accumulation of the bottom of the reservoir in %:

Diameter of particle, mm	40 and more	40÷29	29÷10	10÷5	5 and less
In May	3,2	11,6	18,3	24,6	42,3
Average annual	5,7	28,9	14,8	17,1	38,5

Tables 2 and 3 above describe solid particles, i.e. muddy sediments of the Surkhandarya river. According to the tables, the average annual long-term value of the river sedimentation (according to the Surkhon gauging station) is 7.9 million tons. If their specific gravity is 1.2 t / m3, this means that the sediment discharge is 6.6 million m3 / year [1, 3,4].

The main parameters of the river Surkhandarya river sediments mentioned below in the are calculated on the basis of their mean long-term values.

For estimation of the river sediments following formula is used [7]:

$$\rho = \frac{R \cdot 10^3}{Q} = \frac{1000 \cdot 140{,}6}{69{,}6}\rho = \frac{140600}{69{,}6} = 2020{,}1\,\frac{г}{м^3} = \frac{2020{,}1\ g}{1000\ l} = 2{,}02\,\frac{g}{l}.$$

Calculations of sediment accumulation volume for a certain period are carried out using the following formulas:

a) For describing river sediments accumulation mass following formula is applied:

$$W_{RG} = \frac{R \cdot T \cdot 24 \cdot 60 \cdot 60}{1000} = 86{,}4 \cdot T \cdot R = 86{,}4 \cdot 365 \cdot 140{,}6 = 4433{,}9 \cdot 10^3 tons$$

b) For describing river sediments accumulation volume following formula is used:

$$W_{RV} = \frac{W_R}{\gamma_R} = \frac{4433{,}9 \cdot 10^3 tons}{1{,}15\ tons/м^3} = 3855{,}5 \cdot 10^3 м^3,$$

Where γ_R- describes relative mass of sediment accumulation, in current research we decided as follows: 1, 15 tons /m3.

Assessment module of erosion rate:

$$M_R = \frac{W_R}{F} = \frac{4433{,}9 \cdot 10^3}{8700} = 0{,}509 \cdot 10^3\,\frac{tons}{км^2 \cdot year} = 509\,\frac{tons}{км^2 \cdot year}.$$

Erosion layer estimation:

$$h_{ю} = \frac{W_{RV}}{F} = \frac{3855{,}5 \cdot 10^3 м^3}{8700 км^2} = \frac{3855{,}5 \cdot 10^3 м^3}{8700 \cdot 10^6 м^2} = 0{,}44 \cdot 10^{-3} м = 0{,}443\ мм/year.$$

Estimation of erosion meter:

$$h_э = \frac{1{,}0 м}{h_{ю}} = \frac{1000 мм}{0{,}443\ мм/year} = 2257\ years.$$

The above calculations were also used to determine the maximum (max) and minimum (min) values of river sediment (4-table).

4-table

Hydrological parameters	Sediment values					
	max	min	average	max/min	max/ave.	min/ave.
Q, m³/s	137	24,8	69,6	5,52	1,97	0,36

R, kg/s	488	5,7	140,6	85,61	3,47	0,04
ρ, g/l	3,56	0,23	2,02	15,47	1,76	0,11
W_{RG}, 10^6 t	15,38	0,18	4,43	85,44	3,47	0,04
W_{RV}, 10^6 m^3	13,4	0,15	3,8	89,33	3,52	0,03
M_R, т/km^2year	1767,8	20,7	509,2	85,40	3,47	0,04
H_e, mm/year	1,54	0,02	0,44	77,00	3,50	0,04
H_m, 10^3 year	649	50000	2272	0,01	0,28	22,00

Main hydrological parameters of riverstream, Surkhandarya River hydrologic station Shurchi

Where: Q – water discharge, R – suspended sediment discharge, ρ – average sediment content, W_{RG} – sediment accumulation volume, W_{RV} – volume of sediment, M_R- module of erosion rate, he- erosion layer, hm- erosion meter.

The difference between the maximum and minimum values of the average annual flow rate recorded at the Shurchi hydrological post of the Surkhandarya River is 5.5 times more. The difference between the average annual flow rate and its minimum values is almost 3 times. Such differences are even more clearly explained after the merging of rivers. For example, the average annual minimum value of sediment discharge is 85.6 times less than its maximum. The following conclusions can be made by comparing the remaining values of sediment concentration (ρ), sediment concentration accumulation and volume (W_{RG}, W_{RV}), sediment module (M_R), erosion layer (hp), erosion meter (he).

IV. CONCLUSIONS

Final calculations show that at the Shurchi hydrological station of the Surkhandarya River, the average sediment concentration is 2.02 g/l or 2 kg/m3. River sediments were determined in volume ratios and in masses. Module of erosion is 509 $\frac{tons}{км^2 \cdot year}$, the layer of erosion 0,443 mm/year erosion meter is (intensity of erosion) equals to 2257 years. Consequently, at the Shurchi hydrological station of the Surkhandarya River, the average long-term value of sediment discharge for whole river basin is 140.6 kg/s, therefore the elevation of the river basin decreases by 1 meter over 2257 years. Certainly, this quantity also depends on the natural and anthropogenic factors occur within the basin. It is very important to take into account the effects of potential sediment accumulation in reservoirs because it is one of the key elements in the of a dam project. It becomes even more essential when considering the fact that Uzbekistan is already started to build around 40 small reservoirs in foothill areas.

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