ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
www.ijptonline.com
Research Article

SPATIAL VARIABILITY OF THE PARTICLE SIZE OF RIVER SEDIMENTS INTO WESTERN PART OF THE FORMER USSR

Albert Fargatovich Gilyazov, Anna Alekseevna Kurzhanova
Vadim Vladimirovich Mozzherin
Kazan Federal University, Institute of Environmental Sciences, Kazan.
Email: albert_liberty@mail.ru

Received on 14-08-2016 *Accepted on 20-09-2016*

Abstract

Studying of particle size distribution of river sedimentsand alluvial deposits hasgreat importance for modern geomorphology and paleogeography. In the currentwork impact assessmentof such factors as orography, human activities and river water dischargeon the particle size of uspended sediments and bed materials of the rivers into Western part of the former USSR is attempted. The studied area includesthe Baltic countries, Belarus, Ukraine, Moldova, the countries of Transcaucasia, and the European part of Russia. Division into districts of the explored territory on particle size of river deposits is performed.

With transition Increase in particle size of the suspended sediments and, especially, bed materials from the plains to mountains is observed. This is associated with increase ofaverage relief height that leads to increase in the transporting ability of the rivers. Due the higher transporting ability rivers carry both small and large material.Human activityaffects particle size of the suspended sediments: the share of the small material which arrives from river basin increases in very intensively used drainage area.Particle size of bed materials poorly depends on extent of transformation of landscapes in river basin. Increase in water discharge leads to reduction of particle size of the suspended sediments and bed materials:thin material formed by processes of soil and gully erosion transports to river network. Use of cluster analysis allows receiving evident spatial distribution of particle size of modern river deposits.

Keywords: Suspended sediments, bed materials, the territory of the USSR, the spatial analysis, the factor analysis.

Introduction

The analysis of particle size distribution is a component of one of approaches of a genetic partition of a drain of the suspended sediments on products of a channel and basin origin [1]. Data on particle size distribution of bed materials and river deposits are necessary basic data in different scientific and applied researches [2,3,4]. After R. S. Chalov [5] us the concepts "channel-forming deposits" and "ground (channel, river) deposits" unite. Particle size of river deposits is caused by cumulative influence of a set of factors which value is unequal in different natural and anthropogenous conditions [6]. In the real research influence of an orographical factor, hydrological mode (more precisely – phases of the water mode) and anthropogenous familiarity is considered. Studying of particle size of river deposits most often comes down to a research of influence of various factors on dimension of particles on the example of one or several rivers [4,7]. In similar cases there is no problem of mapping of spatial change of particle size of deposits, however it can be put when studying spatial change of particle size of deposits in more extensive territory. When mapping the similar phenomena it is possible to receive motley, mosaic structure of the explored territory. Therefore in geographical researches quite often there is a need for generalization and generalization of initial material with the purpose to receive the most evident and easily interpreted scheme of division into districts. Recently among a big variety of methods of division into districts the cluster analysis was widely used [6,8,9].

All studies were performed on the project Russian Science Foundation (RSF) "Geography and Geoecology of rivers and river basins of the European Russia: spatial analysis, estimation and modeling".

Methods

Particle size of deposits is expressed in work by the median diameter (Md) which determination was made on a formula of quartiles [10,11]:

$$\mathrm{Md} = \mathrm{x_l} + \mathrm{k}\left(\frac{\mathrm{N_p} - \sum \mathrm{f_{i-1}}}{\mathrm{f_i}}\right),$$

whereMd – size of a required indicator, $\mathrm{x_l}$ – the lower bound of the interval containing$\mathrm{x_p}$, k – interval size, $\mathrm{N_p}$ – 50 %, $\sum \mathrm{f_{i-1}}$ – total frequency is lower than the interval containing$\mathrm{x_p}$, $\mathrm{f_i}$ – frequency of the interval containing $\mathrm{x_p}$.

Data on particle size distribution of deposits for calculation of Md were taken from hydrological reference books [12] in which particle size of tests in various phases of the water mode is presented large, average and small by characteristic structures for the period from the beginning of observations till 1975. In the territory of a research 1215 posts on which for this period sampling of the suspended sediments and/or bed materials with the subsequent determination of content of particles (% on weight) in various fractions was at least once carried out are located. In the real work data on particle size of river deposits from the posts meeting the following requirements were used:

1. The plain rivers with an area of reservoir of 2 000 - 100 000 sq.km (such restriction on the area corresponds to a concept of the zone river). The area of a reservoir of the mountain river does not exceed 50 000 sq.km.

2. The river is considered flat if its reservoir is completely located on the plain; mountain – if mountains occupy not less than 75% of the space of its pool; all other rivers belong to the plain rivers with sources in mountains [13].

3. Not less than 75% of a reservoir of the plainriver are placed in one natural zone [13].

4. Not less than five performed measurements of particle size distribution in each of phases of the water mode.

Pool belonging to this or that natural zone was determined by cards of physiographic division into districts, and to the flat territory or the mountain area – by geomorphological maps of the USSR, Europe and Asia [14]. The plain rivers, in turn, shared on low which average height of a reservoir did not exceed 200 m, and ennobled (from 200 m); the mountain rivers broke on low-mountain with average height of reservoir up to 1500 m, mid-mountain (1500-2500 m) and mountainous (over 2500 m). Borders of reservoirs were determined by cards of scale 1: 100 000 (in rare instances – 1: 200 000). Average height of a reservoir was calculated with application of digital models of a relief of SRTM3' and ASTER GDEM in the ArcGIS software product.

Owing to the fact that the rivers of the explored territory have various types of the water mode, and sampling was made in its various phases, the decision on division of the period, hydrological for about 2 years, – abounding in water and shallow was made. Degree of anthropogenous familiarity of the pool was estimated on the three-point scale offered by A. P. Dedkov and V. I. Mozzherin [13]. Running forward, we will note that not for all posts the anthropogenous familiarity of the pool owing to lack of data on forest coverage and acreness was established.

In work division into districts of the studied territory on particle size of river deposits with application of an agglomerative method of the cluster analysis is made. Division into districts of the territory was made on two signs – the median diameter of deposits and geographical proximity of reservoirs from each other. The second was expressed through the width and longitude of the geometrical centers of reservoirs. These data have various scale therefore there is a need for their rationing: taking into account the choice of a way of determination of proximity between objects (Euclidean distance) median diameter changes from 0 to, and remoteness sign parameters – the width and longitude – from 0 to 1 [5]. The cluster analysis included the rivers of 200 - 100 000 sq.km to a hydrometric alignment. As concentration of posts in the south of the explored territory (The Caucasus, the Carpathians, the Crimean Mountains) big, and particle size of deposits various, – allocation of clusters is difficult here; therefore the cluster analysis of the mountain area in the south was carried out separately from the flat territory and the western slope of the Urals.

Results and Discussion: Orographical factor, through such indicators as falling and a bias of the river, the average steepness of slopes on a reservoir, has significant effect on particle size of deposits. Speed of a current [3] depends on a bias of the river that, in turn, defines the transporting ability of a river stream and the extreme size of transferable material. The steepness of slopes on a reservoir is an important factor of formation of a superficial drain that promotes increase in a share of the small fracture material arriving from the pool [15,16]. In other words, the relief can exert multidirectional impact on particle size of deposits at observance of some other conditions.

According to table 1 it is possible to note influence of a relief on bed materials. In process of transition from the plain rivers to mountain significant increase in particle size of bed materials is observed. On graphics of dependence of particle size of bed materials on the average height of a relief (fig. 1b) close direct dependence with coefficient of determination 0,81 is observed. Formation of large bed materials in mountains is promoted by big biases, and as a result – the high transporting ability of the river: small material is taken out in suspension, and in a carrying state also rather large material is capable to move. On the plain rather low speeds of a current can cause accumulation and rather small (once weighed) material.

Table 1. Influence of a relief on particle size of river deposits (average characteristic structures) during the periods, different in water content.

Reservoir on character of a relief*	Suspended load				Bed materials			
	Shallow period		Highwater period		Shallow period		Highwater period	
	Avg (Md)**	Sample quan-ty	Avg (Md)	Sample quan-ty	Avg (Md)	Sample quan-ty	Avg (Md)	Sample quan-ty
N	0,025	39	0,037	206	0,58	146	0,54	326
V	0,030	23	0,029	96	1,30	57	1,57	109
IS	0,052	13	0,028	66	1,30	28	2,04	48
GN	0,039	66	0,035	319	34,21	120	22,74	185
GS	0,053	100	0,047	364	41,46	61	37,36	152
GV	0,042	19	0,045	57	33,84	11	45,10	29
Without a relief	0,042	260	0,039	1108	17,02	423	13,71	849

Note: * N – lowlands, V – heights, IS – the rivers with sources in mountains, GN – low mountains, GS – average mountains, GV – high mountains; ** Avg (Md) – hereinafter – value of median diameter, average on group, mm.

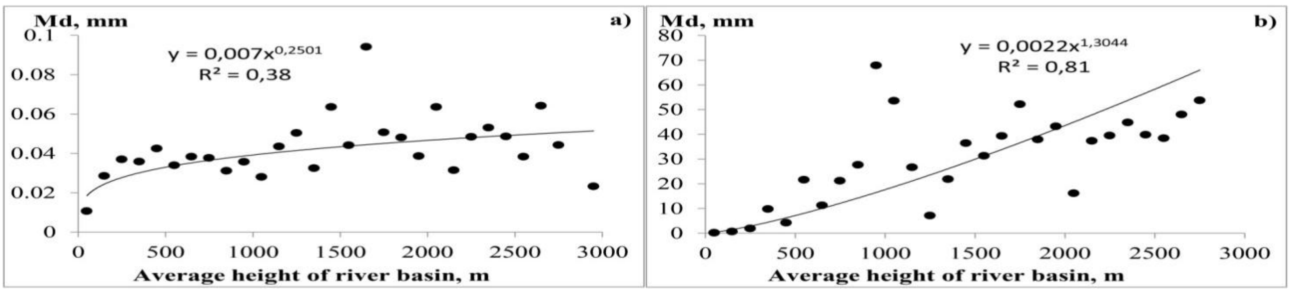

Fig. 1. Schedules of influence of average height of a reservoir on particle size of river deposits: a) the suspended sediments during the shallow period; b) bed materials during the Highwater period. All reservoirs are previously

broken in groups on the average height of a reservoir with an interval of 100 m: <=100 m, 101-200, 201-300 m, etc. In these groups average values of median diameter are received. Influence of a relief on the suspended sediments is not so obvious (tab. 1), however and gradual integration upon transition from plains to mountains is characteristic of them. In fig. 1a the schedule of dependence of particle size of the suspended sediments on the average height of a reservoir is given. Dependence, average on narrowness, with coefficient of determination 0,38 is observed. Most likely, it is connected with the fact that granulometric shape of the suspended sediments here more we depend on factors of anthropogenous familiarity of a reservoir and water content of the river. Existence of the sites unprotected by vegetation on a reservoir and a source of a superficial drain (thawing of snow, draft) promote development of basin system of an erosion. Results of synthesis of data on particle size of deposits in reservoirs of various degree of familiarity are presented in table 2. With increase of a share of the landscape transformed by the person in the pool the tendency to reduction of particle size of the suspended sediments is observed that it is easily explainable: with increase in degree of familiarity of a reservoir the share of basin system erosion grows Change of particle size of bed materials depending on anthropogenous transformation in a reservoir is not shown. Most likely, it is shaded by influence of more significant (for bed materials) factors, first of all, – geological and geomorphological [3].

Table 2. Influence of anthropogenous familiarity of the pool on particle size of deposits of the rivers of lowlands and heights

Degree of familiarity of a reservoir *	Suspended load				Bed materials			
	Shallow period		Highwater period		Shallow period		Highwater period	
	Avg (Md)	Sample quan-ty	Avg (Md)	Sample quan-ty	Avg (Md)	Sample quan-ty	Avg (Md)	Sample quan-ty
I	0,031	3	0,045	28	1,05	32	0,77	79
II	0,030	30	0,032	136	0,77	96	0,98	194
III	0,018	21	0,032	91	0,86	46	0,77	100

Note: * I – the low-changed pools; II – pools with average extent of change of landscapes; III – highly changed pools.

Influence of changes of phases of water content of the river on particle size of deposits is double. On the one hand, increase in water content leads to increase in its transporting ability and by that promotes movement of larger material. On the other hand, heavy expenses are, as a rule, provided including a superficial drain that leads to growth of a share of the particles of the small size arriving from a reservoir surface. Increase in water content (irrespective of a relief) leads to reduction of particle size of the suspended sediments and bed materials (tab. 1) that, most likely, speaks privnosy thin material from the reservoir mobilized by processes of a soil and ovrazhny erosion. In spite of the fact that the transporting ability of the river allows to move and rather large material, – it is leveled in tests by mass character of small material.

At the same time in table 2 the described regularity is not shown in a due measure. If for pools of the I category of familiarity insignificant increase in particle size of the suspended sediments still can be explained with strengthening of the channel washouts delivering large material in a water stream, then in pools of the III category – it increases can be connected only with influence of other (not hydrological) factors. It is not excluded that lack of simple and accurate dependences is connected with incompleteness of the river basins given about degree of economic familiarity.

Conclusions

On the basis of the carried-out cluster analysis the card of spatial variability of particle size of the suspended sediments in the explored territory (fig. 2) was constructed. Clusters with similar intra group medians are noted by the Roman figures of one value, the letter sorts these clusters as increase in particle size of deposits in these groups. The clusters designated by figure I are placed mainly in forest-steppe and steppe zones with some coverage of a subbandthe southern taiga, and also in the Id; particle size of deposits here the smallest. Most likely, it is connected with high degree of familiarity of these pools.

Larger material is formed on East and Western Caucasus, in the basin of the Urals, Western Ciscaucasia and the mountain Crimea, partially in the basins of Dnieper and Don, and also in a zone of a taiga and the tundra. If in the north it can be explained with the fact that pools here are poorly manned, or at all undeveloped, then in all other cases, most likely, are the reasons of such structure of the suspended sediments other mechanisms of their formation. The largest material is formed on other part of the Caucasus, partially in the basins of Dnieper and Don. Particle size of deposits in the Caucasus is defined by the transporting ability of the river which in turn is function of orography and the hydrological mode. Large deposits in the basins of Dnieper and Don are caused, perhaps, by special geological and hydrological conditions.

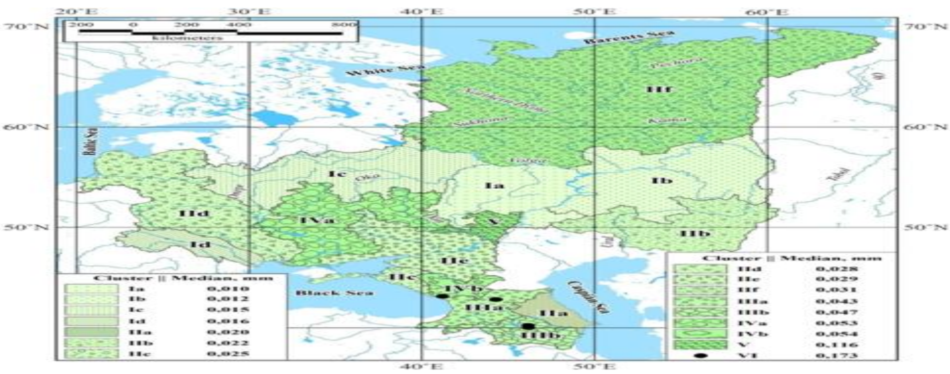

Fig. 2. Spatial variability of particle size of the suspended sediments of the rivers of the western part of the former USSR.

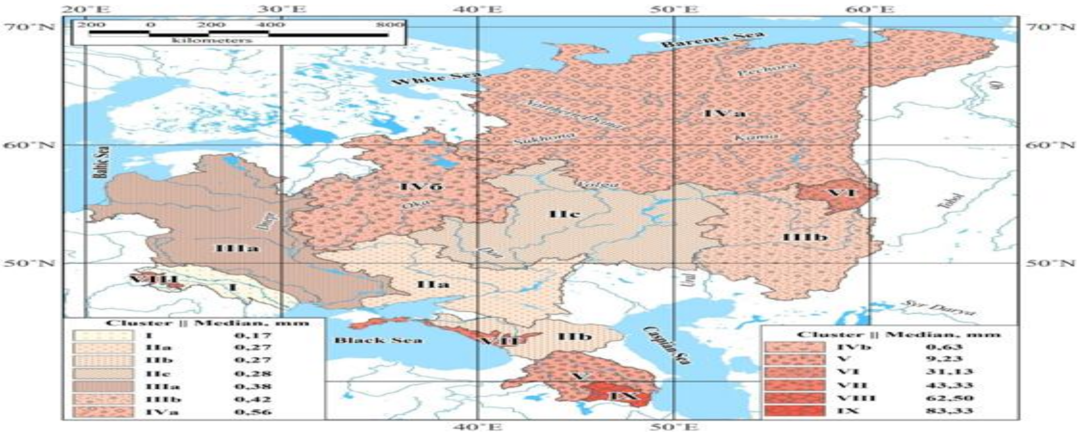

Fig. 3. Spatial variability of particle size of bed materials of the rivers of the western part of the former USSR.

The similar card was constructed for bed materials (fig. 3). The basins of Dniester and the Prut are presented by the smallest bed materials on particle size, even in spite of the fact that their formation happens in the mountain area. Perhaps, it is caused by geology and high degree of anthropogenous familiarity. Larger material is presented on Western Caucasus and to Ciscaucasia, and also in the basins of Don, Middle and Lower Volga (except for the basin of Kama). In the basins of Dnieper, the Urals and Bélaparticle size of deposits is slightly more. Larger bed materials are formed in zones of a taiga and the tundra, and also in upper courses of Volga and Oka. The largest bed materials are presented in mountains: in the Caucasus, Central Ural Mountains and in the Carpathians (an upper course of Dniester and the Prut).

Summary

Summarizing stated, it is possible to draw some conclusions. Such factors as orography, anthropogenous familiarity and the water mode of the river exert impact on particle size of river deposits. Increase in average height of a reservoir leads to increase in particle size of deposits, especially bed materials. The anthropogenous familiarity of a reservoir because of increase in a share of basin system of an erosion promotes reduction of particle size of the suspended sediments. Anthropogenous familiarity of landscapes have no significant effect on particle size of bed materials. Increase in water content of the river leads to reduction of particle size of deposits because of the small material arriving from a surface of reservoirs, but it is irregular for the rivers with the prevailing channel system of an erosion. For receiving more reliable picture of change of particle size of river deposits, it is necessary to consider the existing models of spatial quantitative change of a drain of river deposits [17,18] and influence of other factors (a lithology, natural zonality, a drain overregulation). The cluster analysis is the effective instrument of division into districts of the territory on the studied sign. The smallest material is formed in steppes and forest-steppes, is slightly larger – in northern landscapes, and the largest in mountain areas.

Acknowledgments: The work (translation) is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University. The work (methods, analysis and results) is performed according to the Russian Science Foundation (project №15-17-10008).

References:

1. Gusarov A.V. Riverbed and basin components of erosion and suspended sediments runoff within river basins: A new method of assessment // Geomorfologiya. 2013. Issue 2. – P. 23-39
2. Studying of particle size distribution of bed materials of the rivers / Study guide to managements of Weather Service No. 85. L.: Gidrometeoizdat, 1974.
3. Chernov A.V. The influence of geologic-geomorphologic conditions on the formation and spatial distribution of bedload sediments of the Eastern-Europe's rivers // Geomorfologiya. 2010. Issue 2. – P. 115-120
4. Kumar, A., Gokhale, A.A., Shukla, T., Dobhal, D.P. Hydroclimatic influence on particle size distribution of suspended sediments evacuated from debris-covered Chorabari Glacier, upper Mandakini catchment, central Himalaya // Geomorphology. 2016. Volume 265. – P. 45-67.
5. Chalov of R. S. Canal Science: theory, geography, practice. Volume 1. Channel processes: factors, mechanisms, forms of manifestation and condition of formation of river courses. M.: LKI publishing house. 2008. 608 pages.
6. Gilyazov A. F. The cluster analysis as the instrument of division into districts of the territory on particle size of river deposits (on the example of the basin of Volga)//the Udmurt Bulletin. Univ.. Series "Biology. Sciences about Earth". – 2015. Volume 25, release 2. – Page 149-158.
7. Remo, J.W.F., Heine, R.A, Ickes, B.S. Particle size distribution of main-channel-bed sediments along the upper Mississippi River, USA // Geomorphology. 2016. Volume 264. – P. 118-131.
8. DIDAY, E. AND SIMON, J. C. Clustering analysis. In Digital Pattern Recognition, K.S.Fu, Ed. Springer-Verlag, Secaucus, NJ, (1976). P. 47–94.
9. Jain A. K., Murty M. N., Flynn P. J. Data clustering: a review // ACM Computing Surveys, 1999. V.31, N 3. P. 264-323.
10. Butakov G. P., Dedkov A. P. Analytical studying of big shard material. Kazan: Kazansk publishing house. Univ., 1971. 81 pages.