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METHODS OF COMPLEX ASSESSMENT OF NATURAL AND ANTHROPOGENIC PRESSURE FOR WATER RESOURCES IN CENTRAL ASIA - KARATAL RIVER CASE STUDY

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Development of the national economy in the Karatal basin river is characterized by the progressive involvement and development of the resource potential of natural landscapes, the current rate of utilization of which greatly enhances the anthropogenic impact on the natural environment. A significant impact on the formation of the ecological environment of natural landscapes is provided by the rural and water sectors, as well as by industrial facilities related to processing and mining. At the same time, on the one hand the economic activity of the man in the catchment areas of the river basin gives a certain positive effect, and on the other hand, it is accompanied by an unavoidable set of negative ecological consequences that complicate ecological situations in various ranks of natural systems. Such negative natural and man-caused process in human activity occurs as a result of inadequate knowledge of the regularities of interaction between natural and anthropogenic factors, about the processes developing in the natural environment in complex watershed management, which is one of the obstacles on the way to the creation of ecologically sustainable cost-effective water catchment systems.
Scientific interest to the assessment of the ecological state of the catchments of rivers and the problem of their complex development have been appeared relatively recently which is explained by the increase in modern conditions of anthropogenic load on the catchment areas, the need to assess the impact of such pressures on the ecological stability of catchments and the emergence of the problem of ensuring the sustainable function of catchments. The catena concept was developed to analyze the regular variability of soil on the slope. The example of this approach consists first in a structural component, the recurring pattern of certain soils in a landscape transects in which every chain element has its place in the chain, a soil has it in a landscape areal.
The object of the research is the catchment basin of the Karatal river with a length of 390 km, an area of 19.1 thousand km², which is formed by the merger of three rivers called Tekeliaryk, Chadzha and Kora, sources which are at an altitude of 3200-3900 m. The initial 160 km is mountain character, from the Zhungarian Alatau and below the confluence of Kara and Chizhe River overlooks a wide intermountain plain. Other tributaries are Kara, Terekty, Laba, Balykty, Mokur and the most abundant is Koksu. After the confluence of the tributary of the Koksu River, Karatal flows through the sandy desert of the Southern Balkhash. At a distance of 40 km from the mouth, the river has a delta area of 860 km ^{2}. According to long-term observations, the average annual discharge of the Karatal River in the Ushtobe section is 66.7 m^3/s or 2.1 km^3/ year.

*Keywords**:** geomorphological analysis, indicators of anthropogenic loads, hydrological-climatic assessment, landscape melioration.*

INTRODUCTION

Development of the national economy in the Karatal basin river is characterized by the progressive involvement and development of the resource potential of natural landscapes, the current rate of utilization of which greatly enhances the anthropogenic impact on the natural environment. A significant impact on the formation of the ecological environment of natural landscapes is provided by the rural and water sectors, as well as by industrial facilities related to processing and mining. At the same time, on the one hand the economic activity of the man in the catchment areas of the river basin gives a certain positive effect, and on the other hand, it is accompanied by an unavoidable set of negative ecological consequences that complicate ecological situations in various ranks of natural systems. Such negative natural and man-caused process in human activity occurs as a result of inadequate knowledge of the regularities of interaction between natural and anthropogenic factors, about the processes developing in the natural environment in complex watershed management, which is one of the obstacles on the way to the creation of ecologically sustainable cost-effective water catchment systems. The catena concept was developed to analyze the regular variability of soil on the slope. An example of this approach is based on the structural component, the soil in the landscape.

Scientific interest to the assessment of the ecological state of the catchments of rivers and the problem of their complex development have been appeared relatively recently (Golovanov et al.,2006; Aidarov, 2007; Khafizov, 2009; Burlibaev, M.Zh.; 2014, Kaca, 2017; Ryden et al., 2017; Yunussova and Mosiej, 2016), which is explained by the increase in modern conditions of anthropogenic load on the catchment areas, the need to assess the impact of such pressures on the ecological stability of catchments and the emergence of the problem of ensuring the sustainable function of catchments.

RESEARCH OBJECT AND METHODS

Materials and methods

The object of the research is the catchment basin of the Karatal river with a length of 390 km, an area of 19 100 km², which is formed by the merger of three rivers called Tekeliaryk, Chadzha and Kora, sources which are at an altitude of 3200-3900 m. The initial 160 km is mountain character, from the Zhungarian Alatau and below the confluence of Kara and Chizhe River overlooks a wide intermountain plain. Other tributaries are Kara, Terekty, Laba, Balykty, Mokur and the most abundant is Koksu. After the confluence of the tributary of the Koksu River, Karatal flows through the sandy desert of the Southern Balkhash. At a distance of 40 km from the mouth, the river has a delta area of 860 km ^{2}. According to long-term observations, the average annual discharge of the Karatal River in the Ushtobe section is 66.7 m^3/s, or 2.1 km^3/year (Zhanymkhan et al., 2016).

The concept of a catena was developed in order to analyse the regular variation of soils across a slope. The example of this approach consists first in a structural component, the recurring pattern of certain soils in a landscape transects in which every chain element has its place in the chain, a soil has it in a landscape areal. The concept of a catena was developed in order to analyze the regular variation of soils across a slope. The example of this approach consists first in a structural component, the recurring pattern of certain soils in a landscape transects in which every chain element has its place in the chain, a soil has it in a landscape (Sommer et al. 2000; Young, A. 1972).

The integrated assessment methodology of natural and anthropogenic load of the catchments of the Karatal River basin, taking into account the multidimensionality of the problem, adopts the entire set of existing methodological approaches to environmental management systems, where the catchments are represented by schematized catenes consisting of conjugate facies with different high mutual position, that is, geosystemic and catenary approaches are chosen as priority (Golovanov, 1996, Brudastov, 1934).

On assessing the anthropogenic load, two groups of indicators were taken into account: direct and indirect effects on water bodies and watercourses. The indirect impact on water objects is manifested in the form of anthropogenic loads on the catchment area related to salinization of the territory, economic activities of residents, industrial or agricultural specialization of the economy. The indicators characterizing these factors were used for zoning (ranking) of the Karatal river basin area according to the degree of anthropogenic load.

The following data were used as main (basic): the population density in the catchment area, the density of industrial production (the volume of industrial output in the region in thousands dollars per 1 km^2) and agricultural development including (% arable land) and livestock load (Livestock Units -LSU per 1 km^2).

The used indicators were grouped according to the types of anthropogenic influences: demographic, industrial and agricultural. The agricultural load is obtained as the arithmetic mean of the scores of the intensity use of land (plowing) and livestock loads. The aggregate anthropogenic load was defined as the arithmetic mean of the scores of the demographic, industrial and agricultural load which is based on the methodology of Isachenko, (2001). Table 1 shows the scale of integral criteria for assessing the man-caused load of the natural system, including population density, density of industrial production, level of use of land resources for agriculture, that is, plowing and livestock load.

Table 1. Scale of main indicators for zoning of the territory according to the degree of anthropogenic load (Isachenko, 2001).

The intensity of the load, scores	Indicators			
	Population density people/km^2	Density of industrial production, thousand dollars/km^2	Arable lands (% of plowed land)	Livestock Units (LSU) per 1 km^2
Minor or missing (1)	0.00	0.00	0.00	0.00
Very low (2)	<0.10	<0.35	<0.10	<0.10
Low (3)	0.11-1.00	0.36-3.50	0.11 -1.00	0.11-1.00
Moderate (4)	1.10-1.50	3.60-35.00	1.10-5.00	1.10-2.00
Average (5)	5.10-10.00	36.00-105.00	5.10-15.00	2.10-3.00
Significant (6)	11.0-25.00	106.00-140.00	15.10-40.0	3.10-6.00
High (7)	25.10-50.0	141.0-170.0	40.1-60.0	6.10-10.0
Very high (8)	>50.0	>170.00	>60.0	>10.00

Geomorphological analysis of catchment basins of Karatal River

The geomorphological schematization of the catchment area of the basin of river Karatal was made on the basis of the methodological approach of Golovanov (1993) and is due to the lithological basis and position, which are characterized by heterogeneity in the hydrological regime in the features of the formation of soil-vegetation cover within the ecosystems of its tributaries which depend on the natural and climatic conditions of the region (Mustafaev at al., 2015).

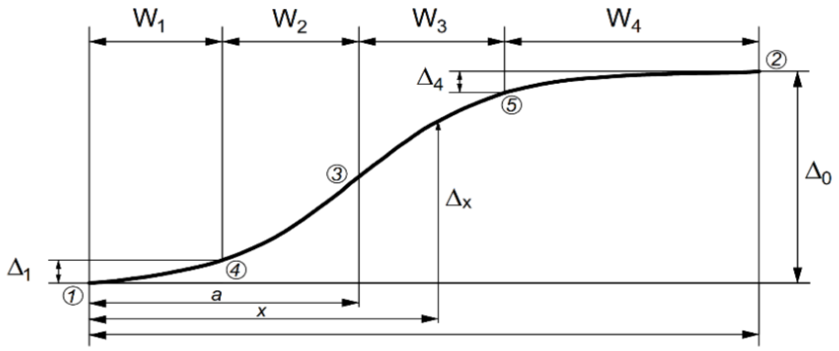

Figure 1. Geomorphological schematization of the landscape catena
(W - the width of the landscape catena W_4, W_3, W_2, *and* W_1 - respectively the extent of the eluvial, transeluvial, trans-accumulative and superaquatic elementary landscapes; Δ_1 and Δ_4 - the height differences of the superaquatic and eluvial elementary landscapes respectively, 1, 2, 3, 4, 5- characteristic points), (Golovanov, 1993).

The catenary approach is the basis for the geomorphological schematization of the catena in support of the need for reclamation of the watersheds of the Karatal river basin, that is, the catchment area is represented by a set of catenes by the number of equal physical and geographical areas in the catchment area (Fig. 1). The geomorphological scheme of the catena consists of four facies with different altitude mutual positions, that is, the *eluvial facies* represent elevation in the watershed lines, and the *transeluvial facies* represent the slope to the point of inflection, the *trans-accumulative* represent the slope after the inflection point, the *superaquatic facies* represent the lowland of the above-floodplain terraces. The *transeluvial* and *trans-accumulative* facies form the transit facies of the slope, and the *superaquatic* facies adjoins the watercourse. Such a schematization differentiates the facies by the type of water supply, that is, takes into account the size and shape of the relief it represents the catena, as an elementary catchment area with its characteristic features (Mustafaev at al., 2015).

The mountainous, foothill, foothill flat and flat landscape zones are distinguished on the territory of the catchments of the Karatal river basin which differ in the sum of biologically active temperatures (t °C), atmospheric precipitation (*P mm)*, evaporation (E_o mm) and photosynthetically active radiation (R kJ/s m^2) (Tab.2).

Climate characteristics of the analyzed area.

1. The mountainous region of the Zhungarian Alatau *(eluvial facies)*, where the hydrothermal coefficient (HTC) is <0.70 with a sum of air temperature above 10° is less than 2800°C.
2. A very arid, foothill zone *(transeluvial facies)* with hydrothermal coefficient (HTC) is 0.50-0.70 and a sum of temperature above 10° equal to 2800-3200°C.
3. Dry moderate zone *(trans- accumulative facies)*, where the hydrothermal coefficient (HTC) is 0.30-0.50 with the sum of the air temperature above 10°C equal to 3200-3500° C.
4. Very dry zone *(superaquatic facies)*, where the hydrothermal coefficient (HTC), which characterizes the moisture and heat availability - 0.20-0.30 with a sum of air temperature above 10° is equal to 3200-3500°C.

Table 2. Physico-geographical zoning of the Karatal river basin

Meteorological station	Elevation H, m	The natural and climatic region on the facies of the catchments of rivers	Indicators of physical and geographical zoning			
			P, mm	$\sum t^o C$	E_O, mm	R, kJ/s m^2
Mountainous class of landscapes or eluvial facies (***W₄***)						
Kugaly	1365	Mountainous	350	2250	675	149.0
Kos-Agash		Mountainous	345	2300	690	150.8
Foothill subclass of landscapes or transeluvial facies (W_3)						
Saryozek	948	Foothill	270	3000	900	175.9
Taldygurgan	602	Foothill	230	3100	930	179.5
Foothill flat subclass of landscapes or trans-accumulative facies (W_2)						
Ushtobe	428	Foothill -flat	212	3180	954	182.4
The flat class of landscapes or superaquatic facies (W_1)						
Naimensuiek	349	flat	195	3200	960	183.0

On the basis of Tab. 2 the geomorphological schematization of the catchment area of the Karatal River basin was developed from the eluvial (W_4) to the suberaquatic facies (W_1), where the altitude of their location gradually decreases, which makes it possible to base them on the basis of geomorphological schematization of the landscape catenes of the catchment area (Table 3).

As it can be seen from *Table 3* the above given catchment classification of the Karatal basin river as a whole coincides with natural-climatic and landscape zoning, that is, the first classification relies on relative values (for example: the degree of moistening) and the second is on absolute values (for example, the land relief). Because of this, small inconsistencies between classifications are observed and it is necessary to determine the main classification (Golovanov et all., 2006, Aidarov 2007, Zhanymkhan et all.,2016).

Table 3. Geomorphological schematization of landscape catchment area of the Karatal river basin

Natural and climatic zones		Geomorphological indicator (absolute height of the earth's surface, m)	Administrative districts
Class of landscape	Facies		
Mountainous	Eluvial W_4	<1400	Kerbulak region Koksu region
Foothill	Transeluvial W_3	600-1400	Kerbulak region Eseldy region Koksu region
Foothill –flat	Trans-accumulative W_2	450-600	Eseldy region Karatal region
Flat	Superaquatic W_1	>450	Karatal region

Due to the climatic heterogeneity of the territory and the mountain-plain relief the soil cover of the Karatal basin is very diverse. The natural and climatic indicators of catchments are characterized by: hydrothermal coefficient ($HTC = 10 \cdot P / \sum t$), coefficient of moistening C_m ($Cm = P / E_o$), moisture assessment ($C_a = P / 0.18 \sum t$), dryness index ($\overline{R} = R / L \cdot P$), biological and climatic productivity ($BCP = C_m (\sum t / 1000)$).

As it can be seen from Table 4, the Karatal River basin has enough high heat supply, since *HTC=0.60*-1.55 and $\overline{R}$ =1.71-3.75 are quite high. However, the moisture availability of the basin is very low *(C_m= 0.20-0.52)*, which determines the peculiarity of the formation and functioning of landscape systems.

Table 4. Hydrological-climatic assessment of heat and moisture availability of the Karatal River basin

Meteorological station	Elevation H, m	Average annual for a long-term period				
		$\overline{R}$	*HTC*	*BCP*	C_m	C_a
Mountainous class of landscapes or eluvial facies (W_4)						
Kugaly	1365	1.71	1.55	1.17	0.52	0.86
Kos-Agash	1300	1.75	1.50	1.15	0.50	0.83
Foothill subclass of landscapes or transeluvial facies (W_3)						
Saryozek	948	2.50	0.9	0.90	0.30	0.50
Taldykorgan	602	3.12	0.7	0.78	0.25	0.43
Foothill flat subclass of landscapes or trans-accumulative facies (W_2)						
Ushtobe	428	3.44	0.7	0.70	0.22	0.37
Flat class of landscapes or superaquatic facies (W_1)						
Naimensuek	349	3.75	0.6	0.64	0.20	0.34

The classification according to natural – climatic parameters is more suitable for a complex arrangement, combining the catchments and their catenes into the same type of landscape groups by the most significant indicators for heat and moisture availability R= 5 -6. According to this classification, it is necessary to carry out the justification of melioration of agricultural lands and the optimization of the catchment infrastructure with their complex arrangement of the Karatal river basin.

RESULTS OF THE RESEARCH

In the catchment basin area of the Karatal river there are four districts of Almaty region, they are: Eskeldy, Kerbulak, Koksu and Karatal with a total area of 4 669 056 ha and a population of 191 279 people (Table 5) (Statistical Yearbook, 2012).

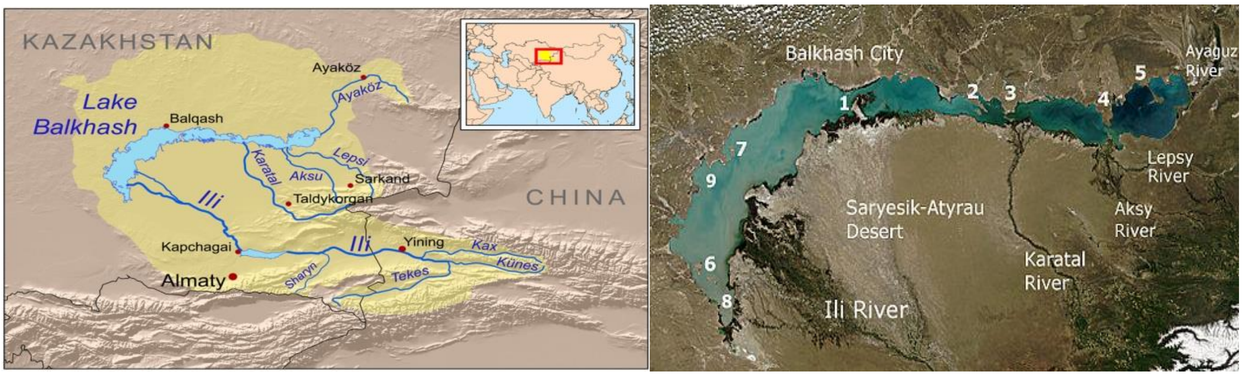

Figure 2 Map of the Lake Balkhash drainage basin with Karatal river. https://en.wikipedia.org/wiki/Lake_Balkhash

Taking into account the natural-climatic conditions of landscape systems, the main agricultural crops are cultivated to meet the needs of the population in the basin of the Karatal river (Table 6) (Statistical Yearbook 2012). As it can be seen from Table 6, the main areas of agricultural land are occupied by wheat and barley with a total area of 118 600 hectares of which about 101 000 hectares of rainfed lands are located in the foothills of the Eskeldy and Kerbulak districts of Almaty region.

Table 5. Total land area and distribution of agricultural land in the Karatal river basin

Administrative districts	Population (number of people)	Total land area, ha	Agricultural land, ha	Including		
				arable land	meadows hayfields	pastures
Eskeldy	50436	803 730	580 002	55968	16035	506276
Kerbulak	51894	1 116 575	922 628	130549	19988	761351
Koksu	40286	697 704	650 657	31549	9308	599039
Karatal	48663	2 051 047	1 792 228	19964	14342	1753855
Total	191279	4 669 056	3 945 515	238030	59673	3620521

The soybean area prevails in irrigated lands which in the basin of the Karatal River is about 19100 hectares, as well as vegetable crops with a total area of 9700 ha. At the same time, one of the water-intensive crops - rice is cultivated on the territory of the Karatal district with an area of 4100 hectares, which shows a certain balance in the structure of agricultural lands of the Karatal river basin. However, the productivity of agricultural crops is relatively low, which requires the need for improving the technology of cropping (Table 7) (Statistical Yearbook, 2012) .

Table 6. Crop area and structure of agricultural crops which are cultivated in the Karatal river basin

Crops	Administrative regions which are located in the Karatal river basin, ha				
	Eskeldy region	Kerbulak region	Koksu region	Karatal region	Karatal river basin
Wheat	12000	28400	7600	3700	51700
Barley	13500	47100	5200	1100	66900
Corn for grain	800	300	300	700	2100
Rice	-	-	-	4100	4100
Sunflower	900	100	300	200	1500
Soybean	10400	-	7700	1000	19100
Sugar beet	1000	-	2700	400	4100
Potatoes	2200	2400	900	1100	6600
Vegetables	900	500	800	1500	3700
Total	40890	78800	25500	13800	158990

The livestock breeding has developed in the basin of the river Karatal, which has certain natural resources, that is, in these regions there are hayfields and pastures that ensure their livelihoods (Table 8) (Statistical Yearbook,2012)..

Table 7. Productivity of agricultural crops in the Karatal river basin

Crops	Administrative regions which are located in the Karatal river basin, tons/ha				
	Eskeldy region	Kerbulak region	Koksu region	Karatal region	Karatal river basin
Wheat	24.0	17.8	24.7	17.0	20.9
Barley	23.1	18.3	23.7	15.3	20.1
Corn for grain	57.4	37.0	60.8	52.0	51.8
Rice	-	-	-	38.5	38.5
Sunflower	11.2	12.3	13.0	17.3	13.4
Soybean	19.2	-	21.3	13.2	17.9
Sugar beet	329.4	-	267.1	267.1	237.9
Potatoes	164.4	193.6	193.0	187.0	184.5
Vegetables	184.2	241.2	318.0	285.0	257.1

As it can be seen from Table 8, the livestock load is mainly distributed unevenly across the territory of the districts, that is, despite the large enough occupied total area and including pasture land, the smallest number of animals is observed in the Karatal region.

Table 8. Livestock animals in the Karatal river basin

Types of animals	Administrative regions which are located in the Karatal river basin, heads				
	Eskeldy region	Kerbulak region	Koksu region	Karatal region	Karatal river basin
Cattle	26700	22800	30800	44600	124900
Dairy cows	13800	21600	11800	12000	59200
Pigs	4600	1200	4200	9100	19100
Sheep and goats	112500	200000	128900	81500	522900
Horses	7100	13500	8600	6600	35800
Total	164700	259100	184300	153800	761900

In connection with the existing systems of nature management with primary development of mining, which mainly from the volume of industrial production in the Karatal basin (Tab. 9) (Statistical Yearbook, 2012).

Based on the data given in Tables 5-9, the calculations were carried out in the Karatal river basin, which revealed the following differentiation of the natural and anthropogenic loads. By Isachenko (2001) criterion, a large enough drop is obtained on the scale and it is very difficult to determine accurately, therefore we took the maximum values of the environment of the 4 indicators themselves (Table 10).

Table 9. The volume of industrial and agricultural production by main activities in the Karatal river basin

Indicators	Administrative regions which are located in the Karatal river basin, million tenge				
	Eskeldy region	Kerbulak region	Koksu region	Karatal region	Karatal river basin
Gross agricultural production:	11893.1	14099.3	9249.2	10265.0	45506.6
- plant production	7362.8	8039.3	5549.7	6667.5	27619.3
- animal husbandry	4608.4	6073.2	3703.2	3706.6	18091.4
Mining industry	15.5	656.7	23.7	34.8	730.7
Manufacturing industry	4455.9	407.4	3510.8	1708.9	10083.0
Other production	4387.8	6.2	3061.7	1394.8	8850.5
Total	32723.5	29282.1	25098.3	23777.6	110881.5

The moderate (4) *anthropogenic load* (4 points) is observed in the territory of the Karatal district of Almaty region, where the density of population is 0.237 people/km^2, the density of industrial production is 0.342 thousand dollars/km^2. The territory is characterized by the lowest for the considered basin with agricultural assimilation with a level of plowing 0.007% and livestock load of about 0.750 LSU/km^2.

Table 10. Indicators of anthropogenic loads in the catchment basin of the river Karatal

Indicators	Indicators of anthropogenic loads in the catchment basin of the river Karatal Final scores of evaluation of the intensity of the load/number of points for selected indicators *(results of evaluation in brackets*).				
	Eskeldy region	Kerbulak region	Koksu region	Karatal region	Karatal river basin
Total area, km^2	80373	111657.5	69770.4	205104.7	466905.6
Population, people/person	50436	51894	40286	48663	191279
Population density, people / km^2	0.530 **(3)**	0.460 **(3)**	0.577 **(3)**	0.237**(3)**	0.410 **(3)**
Area of irrigated land, ha	40890	78800	25500	13800	158990
% of plowed land	0.050 **(2)**	0.070 **(2)**	0.036 **(2)**	0.007 **(2)**	0.034 **(2)**
Livestock load, LSU/km^2	2.050 **(5)**	2.320 **(5)**	2.542 **(5)**	0.750 **(3)**	1.532 **(4)**
Density of industrial production, thousand dollars /km^2	1.192 **(3)**	0.767**(3)**	1.064 **(3)**	0.342 **(2)**	0.703 **(2)**
Located water resources, km^3	0.381	0.363	1.166	0.380	2.29
Specific water availability per inhabitant, thousand m^3/person	7.566	6.395	23.943	7.308	11.972

Final scores of evaluation of the intensity of the load/number of points on the basis from tab.1 (*note: the indicators are not summarized but take their maximum value).*

The average anthropogenic load (5 points) is typical for the largest group, which includes the Eskeldy, Kerbulak and Koksu districts, where the population density is 0.460-0.577 people / km^2, the density of industrial production varies from 0.767-1.192 thousand dollars / km^2, the level of plowing from 0.005 to 0.034%, livestock load from 2.050 to 2.542 LSU/km^2.

SUMMARY AND CONCLUSIONS

The methodology for assessing pressure on water resources presented in works resulting from both natural conditions and business activities in the catchment (both agricultural and industrial) may allow making rational decisions regarding the development directions of the catchment areas. Of course, the authors are aware of the imperfection of the methodology resulting primarily from the use of many statistical information, as well as meteorological and hydrological information. The analyzed area, due to its specificity (freshwater and saltwater in Lake Balkhash, cross-border nature of rivers flowing into the lake) requires a special approach. However, the methodology presented in the work can be used in other areas. Of course, we can argue about the ranges and volumes of data used, but the methodology can be universalized and applied in other areas. Depending on the general statements and wording contained above, the following more specific conclusions can be made:Based on the use of statistical materials of the Almaty region of the Republic of Kazakhstan using the scale of the main indicators for the zoning of the territory in terms of the degree of anthropogenic load, the proposed methods was carried out in the catchment area of the Karatal basin in the context of administrative districts to estimate the man-caused loads. At the same time, the level of anthropogenic load is determined by the maximum quantitative values of the scale of the main indicators for the types of anthropogenic load.

2. For a comprehensive arrangement, the classification according to natural and climatic indicators is more suitable, combining watersheds and their catens into similar landscape groups by the most significant indicators for heat and moisture availability. According to this classification, it is necessary to carry out the justification of land reclamation and the optimization of the catchment infrastructure in the complex development of the Karatal river basin.
3. Generally, according to the geoecological load, as a result of the anthropogenic activities of the Karatal river basin, it is not high, that is, the basin belongs to the region with not a high anthropogenic load. In general, the Karatal river basin has fairly high water availability, but it is characterized by a high degree of contamination, both locally and regionally, due to the development of mining and manufacturing industries. The aggregate anthropogenic load on the territory of the Karatal river basin increases downstream of the rivers reaching the greatest values in the mouths of Lake Balkhash
4. At present, we want to develop a system of models that combine 4 indicators and based on Isachenko (2002) integral criteria, that is, the scale of integral criteria for assessing the man-made load of the natural system will have certain quantitative values.

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