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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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THE METHODS OF ASSESSMENT OF MAXIMUM ALLOWABLE IMPACTS ECOLOGICALLY ON SMALL RIVERS

Abstract. On the basis of the existing mathematical models of the productivity of the water environment allowing to define the ecologically allowable limits of anthropogenic impact on the basis of the principle of Le Chatelier-Braun, one of the modifications of mathematical models, based on the equation of hydro-chemical balance of substances in river basins, describing the state of the water system with all the natural and anthropogenic factors, characterizing the state of the water ecosystem in a state of stable equilibrium are carried out.

Keywords: model, assessment, resources, nature, river flow, water discharge, return water, water consumption, pollution, function, salt, factors.

Introduction. Small rivers are the complex of natural objects, creating the characteristic natural of landscape, differentiated by the specific hydrological regime (with a decrease in the size of the river increases intra uneven runoff) underwater regimes, which are characterized by a wide variety of forms, determined by a combination of climatic conditions and land and plant covers and forming a close connection forming with the landscape runoff catchment area, which makes them highly vulnerable to the complex arrangement of catchments of river basins.

One of the main tasks of the complex arrangement of catchments of small rivers to improve the ecological and social-economic conditions of the territories, that is, to determine the level of anthropogenic impact on the natural geo-ecosystems, to reduce the techno-genic impacts on natural geo-ecosystems per set to reduce consumption of natural resources per unit of output by improving the technology production, to save and to restore the properties of geo-ecosystems and their habitat value by optimizing the use of natural resources without bringing natural ecosystems beyond their resilience.

In this regard there is a need to discuss a number of methodological issues in the assessment of maximum allowable impact on small rivers: firstly, it should be noted a different level of current knowledge and understanding of the mechanisms of formation and development of the various components of the environment; secondly, ecosystem actions of forecasts in the changed conditions are based on the laws, received in relation natural conditions; thirdly, involving natural objects in natural and technical systems stimulates the proliferation of existing concepts in the technical sciences and natural components

Accordingly, the basis for the development of methodology for assessing ecologically maximum allowable impact on small rivers should be carried out on the basis of the analysis of hydrological, hydrobiological, hydro-chemical and hydro-geological features, as indicators of the functioning of aquatic and riparian ecosystems, allowing to estimate as the admissibility of the planned breach of the catchment basin of the water regime of small rivers.

Objective of research. The main objective of research is to develop one of the modifications of mathematical models, on the base of the equation of hydro-chemical balance of substances in river basins, which describes the behavior of the water system with all the natural and anthropogenic factors that characterize the actions of the aquatic ecosystems being in a state stable of equilibrium for the assessment of ecologically maximum allowable impact on small rivers.

The analysis of the latest researches and publications on the issue. The carried out analysis works on the assessment of the environmental impact of maximum allowable anthropogenic load at the pools of small rivers showed that G.V. Dobrovolsky [1], V.F. Protasov, A.B. Molchanov [2], A.P.Khaustov [3], T.A. Triphonova [4], F. Anderson [5], M.J. Hammer, K.A. Mc Kichan [6], B.D. Richter, D.P. Braun, M.A. Mendelson, L.L. Master [7], the drainage basin is considered as a complex fundamental of ecological system that is formed by geo-evolutional ways and having the natural border. Given the complexity of biological, geochemical transformations and migrations of pollutants, G.V. Dobrovolsky [1], A.P. Khaustov [3], T.A. Trifonova [4], M.A. Glazovskaya [8], G. Odum, E. Odum [9], J.S. Baron, N.L. Poff, P.L. Angermeier, C.N. Dahm, P.H. Gleick, N.G. Hairston, R.B. Jackson, C.A. Johnston, B.D. Richter A.D. & Steinman [10], E. Carral., X. Puente [11], R. P. Howmiller, A.M. Beeton [12], D.L. King, R. C. Ball [13], J. B. Loomis, R.G.Walch [14], R.T. Oglesby [15], A.M.Sutterlin [16], J. Verneaux [17] the catchments area of the river are considered as the anthropogenically the changed landscapes or «landscape-geochemical system». R. Pentl [18], J. Smith, [19], John. Jeffers [20], L.A. Petrosyan [21], J.R. Chandler [22], C.E. Shannon [23], N.M. Straalen, C.AJ. Denneman [24], S.W. F. Van der Ploeg, L. Vlijm [25] the task of eco-logization of catchment basin of small rivers are considered by the fundamental principles of systems analysis, management, ecology, methods of mathematics and computer science techniques for the purpose of mathematical modeling and prediction of the status and development of ecosystems, in particular, their self-cleaning capacity. I.I. Mazur and O.I. Moldavanov [26], T. O 'Donnel [27] attempted mathematical description by differential equations, which illustrate the processes of human transformation of the landscape.

In the works of T.A. Akimov and Haskin [28] the method of determining the maximum allowable anthropogenic load on ecosystems, assessment of crisis scenarios in the case of excess capacity techno and select the most appropriate (on economic grounds) variant management solutions are provided.

N.N. Moiseev, V.V. Aleksandrov, A.M. Tarco [29] proved that for an acceptable level of impact on the river can be done with functions allowing to describe the actions of the water system in a state of stable equilibrium, taking into account the impact of natural and anthropogenic factors.

The basic methodical positions estimate of allowable exemptions flow in small river basins developed by V.I. Danilov-Danillyan, M.V. Bolgov, V.G. Dubinin, V.S. Kovalevsky, A.G. Kochariyan, and N.M. Novikov [30], the method of determination of ecologically allowable impact on small rivers are presented in the works of V.N. Markina [31] and G.V. Belonenko, N.B. Popov [32], Kairanbayeva G.K., Nyussupova G. N., Arslan M. [33], Nogica M., Scibanb M., Savicc M., Jolovicd B. [34], Kukeyeva F.T., Delovarova L. F., Ormysheva T. A., Shakirov K. N. [35] suggested that assessment methods of maximum allowable impact on the water objects and methodical bases of its definition.

Research object is the Karatal River on hydrological characteristics relating to the category of small rivers.

On the basis of many years of information and analytical materials of «Kazhydromet» RSE the systematization and system analysis for evaluating the changes of mineralization and the chemical composition of water of Karatal Rivers in the result of anthropogenic activities (table 1) are produced.

As it can be seen from table 1, the hydrochemical composition of river flow is very complex and quite high, as well as the salt and heavy elements (table 2) affecting by productivity of water vegetation are found in the composition of the bottom sediments.

In the river Karatal the average mineralization of water is 153 mg/dm^3 when the stiffness of 1.9 mEq/dm^3, pH water made 8.12. The predominant ions in the water of river Karatal occur hydrocarbons and calcium ions (HCO^3 - and $Ca^{2+)}$, the index of water on Alekinu CCaII. The level of high water pollution in the city Taldykorgan (Ekpendy village) made 2.62, accordingly the water quality refers to «dirty» class 4. Pollution of the river is noted by total iron (2.2 MAC) of copper (8.4 MAC), manganese (2.5 MAC) and nitrite nitrogen (1.48 MAC). Downstream, in the village of Ushtobe the water quality also applies to Class 3. WPI (Water pollution index) made 1.87, copper (5.0 MAC) and total iron (1.55 MAC) is revealed by exceeding the MPC. Pollution of the river is noted by manganese (1.8 MAC) and nitrite nitrogen (1.6 MAC) [36].

Table 1 – Changes of mineralization and chemical composition of the water (mg /l) of Karatal River

River-station	Years	The main ions, mg / l					
		HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	mineralization
Karatal–Taldykurgan (Ekpendy)	1998	67,1	43,2	4,4	15,0	3,7	160,3
	1999	85,4	13,2	3,5	26,5	5,5	134,2
	2000	48,8	16,8	8,9	18,0	1,2	103,7
	2001	110,7	14,4	5,3	16,0	3,0	165,7
	2002	82,4	9,6	5,3	21,0	4,3	130,1
	2003	161,7	9,61	8,86	42,0	12,81	150,3
Karatal–UshTobe	1998	67,1	57,6	6,2	25,0	4,9	181,5
	1999	85,4	50,4	4,2	26,5	5,6	191,7
	2000	57,9	12,0	5,3	14,0	2,4	103,0
	2001	57,9	14,4	5,3	17,0	3,0	106,5
	2002	76,3	9,6	5,3	21,0	4,3	211,5
	2003	100,68	26,42	5,32	29,0	4,81	251,2

Table 2 – Characteristics of contamination of bottom sediments of the river of Karatal with heavy metals (mg/kg)

Indicators	Sampling site				
	City –Taldygurgan (Ekpendy village)				
	2010	2011	2012	2013	2014
Chromium (Cr)	0,08	0,08	0,145	0,08	0,025
Nickel (Ni)	0,89	12,8	13,43	0,665	1,2
Arsenic (As)	2,7	0,96	1,69	0,79	2,76
Copper (Cu)	0,5	1,28	1,04	0,925	0,72
Cadmium(Cd)	0,87	1,95	1,16	0,175	0,10
Lead (Pb)	1,9	2,9	2,1	11,14	21,26
Manganese (Mn)	750,5	847,1	699,4	867	846,9

In this way, the changes in of mineralization and the chemical composition of water of Karatal River and the pollution of its bottom sediments with heavy metals on the intensity of Incoming pollution depends largely on the result of anthropogenic activities, which exert a definite influence of formation of productivity of aquatic vegetation as an indicator characterizing its hydrochemical conditions that determine the environmental sustainability of river ecosystems and maximum - permissible level of use of water resources of small rivers.

In this regard, there was a need to develop the system of mathematical models allowing to predict the environmental sustainability of river ecosystems and the maximum permissible level of use of water resources taking into account the change of mineralization and the chemical composition of water of small rivers in the result of anthropogenic activities.

Results. The anthropogenic impact on water objects are primarily due to their exhaustion as a result of water abstraction and pollution with wastewater discharges that contribute to the deterioration of the ecosystem, and at a certain level of external action, the ecosystem of the river basin small loses the ability to stand up to them losing their environmental sustainability. Therefore, when planning the use of natural resources of small rivers catchment area need to know the ecologically maximum allowable level of irrevocable water consumption and pollution.

Herewith the natural features of small rivers, that is, relatively small amounts of runoff, low limits of self-purification processes, significant dependence on the state of the catchment area, which is characterized by an increased sensitivity to human impacts, that as exceeding the limits of ecologically allowable anthropogenic impact leads to the reduction and loss of natural and anthropogenic, and further the natural functions of small river (figure 1).

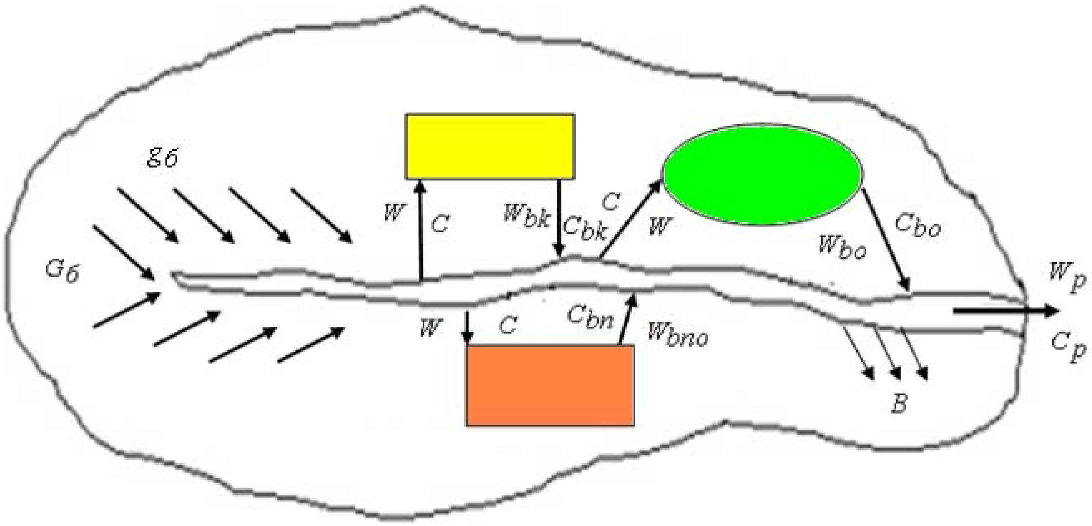

Figure 1 – The scheme for drawing up of the equation of hydro-chemical balance of watersheds of small rivers

For this, we consider the environment-forming factors of small rivers, where the functions that describe the action of the water system we use the equation hydrological and hydro-chemical substances for the average annual balance of the year conditions (figure 1):

$$W_p = W_б + W_b - W_{bn} + W_{n3}; \; G_p = G_{pn} + G_б + G_b + G_n - B,$$

they are W_p - the volume of river flow; W_b - the volume of return water: $W_b = W_{bk} + W_{bno} + W_{bo}$, W_{bk} - the amount of return water of urban public utilities; W_{bno} - the volume of return water of industrial facilities; W_{bo} - the volume of drainage water from irrigated lands; W_{bn} - the volume of water consumption; $W_б$ - the volume of water coming from the catchment area: $W_б = g_б \cdot F_б$, $g_б$ - a module of water runoff from the catchment area; $F_б$ - the catchment area; G_p - the mass of soluble salts in the hydrographic network: $G_p = W_p \cdot C_p$, C_p - the concentration of substances in the river water; G_b - receipt of the mass of soluble salts to the volume of return (waste) water treatment: $G_b = W_b \cdot C_b = W_{bk} \cdot C_{bk} + W_{bn} \cdot C_{bn} + W_{bo} \cdot C_{bo}$ - the concentration of a substance in return waters; C_{bk} - the concentration of a substance in return waters of urban public utilities; C_{bn} - the concentration of a substance in return waters of industrial objects; C_{bo} - the concentration of substances in drainage waters; $G_б$ - the mass of soluble salts coming from the catchment area: $G_б = g_{bб} \cdot F_б$, $g_{bб}$ - the specific removal of the substance from a unit of the catchment area; G_{bn} - the mass of soluble salts, water consumption picks up at: $G_{bn} = W_{bn} \cdot C_p$; B - the amount of the substance absorbed by aquatic vegetation; G_{n3} - the mass of soluble salts from the groundwater: $G_{n3} = W_{n3} \cdot C_{n3}$; G_{pn} - the mass of soluble salts from the channel flow.

The amount of the substance absorbed by aquatic vegetation in the basin depends on the volume of water in the river (W_p) and its pollution (C_p), that is determined by the following equation: $B = B_{\max} \cdot S(w) \cdot S(c)$,where $B_{\max}$ - is the maximum amount of a substance absorbed by aquatic vegetation:, $B_{\max} = b_{\max} \cdot W_б$, $b_{\max}$ - maximal volume of the substance absorbed by aquatic vegetation of unity volume of water; $S(w)$ - the relative productivity of aquatic vegetation depends on the volume of water in rivers; $S(c)$ - the relative productivity of aquatic vegetation depends on water pollution in rivers.

For evaluating the conditions of the formation of hydro-chemical flow regime of river basins consisting of the substances of the balance equation can be represented in the following form:

$$W_p \cdot C_p = g_{bб} \cdot F_б + W_b \cdot C_b - W_{bn} \cdot C_p + W_{nз} \cdot C_{nз} - B_{\max} \cdot S(w) \cdot S(c).$$

As this the volume of return water can be submitted on the following form:

$$W_b = K_b \cdot W_{bn} = K_{bk} \cdot W_{bk} + K_{bno} \cdot W_{bno} + K_{bo} \cdot W_{bo},$$

where there are K_b - coefficient of return water; K_{bk} - the coefficient of return water of urban public utilities; K_{bno} - the coefficient of return water of industrial facilities; K_{bo} - coefficient of return water from irrigated lands.

For the purpose of simplifying the tasks, an equation of hydro-chemical balance of substances of river basins; we represent them in the following ways:

$$W_p \cdot C_p = g_{bб} \cdot F_б + W_b \cdot C_b - W_{bn} \cdot C_p + W_{nз} \cdot C_{nз} - B_{\max} \cdot S(w) \cdot S(c).$$

Given that $W_b = K_b \cdot W_{bn}$ the equation hydro-chemical balance of river basins substances can be written in the following form:

$$W_p \cdot C_p = g_{bб} \cdot F_б + W_{bn} \cdot K_b \cdot C_b - W_{bn} \cdot C_p + W_{nз} \cdot C_{nз} - B_{\max} \cdot S(w) \cdot S(c).$$

If the ratio of the volume of river flow (W_p) to the household drains of the river ($W_б$), we denote by A, in this case, the equation of hydro-chemical balance of river basins substances will take the following form:

$$A \cdot C_p = \frac{g_{bб} \cdot F_б}{W_б} + \frac{W_{bn} \cdot K_b \cdot C_b}{W_б} - \frac{W_{bn} \cdot C_p}{W_б} + \frac{W_{nз} \cdot C_{nз}}{W_б} - \frac{B_{\max} \cdot S(w) \cdot S(c)}{W_б}$$

or

$$A \cdot C_p = \frac{g_{bб}}{g_б} + \frac{W_{bn}}{g_б \cdot F_б}(K_b \cdot C_b - C_p) + \frac{W_{nз} \cdot C_{nз}}{g_б \cdot F_б} - \frac{B_{\max} \cdot S(w) \cdot S(c)}{g_б \cdot F_б}.$$

After some transformations the equation hydro-chemical balance of river basins substances we get as follows:

$$A \cdot C_p = \frac{g_{bб}}{g_б} + \frac{g_{bn}}{g_б}(K_b \cdot C_b - C_p) + \frac{g_{nз} \cdot C_{nз}}{g_б} - \frac{b_{\max} \cdot S(w) \cdot S(c)}{g_б}$$

or

$$A \cdot C_p + \frac{g_{bn}}{g_б} \cdot C_p = \frac{g_{bб}}{g_б} + \frac{g_{bn}}{g_б} \cdot K_b \cdot C_b + \frac{g_{nз} \cdot C_{nз}}{g_б} - \frac{b_{\max} \cdot S(w) \cdot S(c)}{g_б}.$$

To evaluate the changes in the concentration of river flow, reduced balance equation substances in river basins hold some transformations, that is:

$$C_p(A + \frac{g_{bn}}{g_б}) = \frac{g_{bб}}{g_б} + \frac{g_{bn}}{g_б} \cdot K_b \cdot C_b + \frac{g_{nз} \cdot C_{nз}}{g_б} - \frac{b_{\max} \cdot S(w) \cdot S(c)}{g_б}$$

or

$$C_p(A \cdot g_б + g_{bn}) = g_{bб} + g_{bn} \cdot K_b \cdot C_b + g_n \cdot C_n - b_{\max} \cdot S(w) \cdot S(c),$$

The converted substances balance equation we solve relatively C_p, then we get:

$$C_p = \frac{g_{bб}}{(A \cdot g_б + g_{bn})} + \frac{g_{bn} \cdot K_b \cdot C_b}{(A \cdot g_б + g_{bn})} + \frac{g_n \cdot C_n}{(A \cdot g_б + g_{bn})} - \frac{b_{\max} \cdot S(w) \cdot S(c)}{(A \cdot g_б + g_{bn})}.$$

As it can be seen from the structure of the balance equation of substances in river basins of the external impact on the river ecosystem is characterized by the first three terms, and using them can estimate the concentration of water in river basins, depending on the level of anthropogenic impact of human activities:

$$C_{pm} = \frac{g_{bб}}{(A \cdot g_{б} + g_{bn})} + \frac{g_{bn} \cdot K_b \cdot C_b}{(A \cdot g_{б} + g_{bn})} + \frac{g_n \cdot C_n}{(A \cdot g_{б} + g_{bn})},$$

They are C_{pm} - the concentration of water of river basins, formed under the influence of human activities.

Therefore, when it is known the concentration of the river basins of water depending on the level of anthropogenic impact of human activities (C_{pm}), then we can determine the concentration of the river basins of water in view of self-purification of water with aquatic vegetation activity according to the following relation:

$$C_p = C_{pm} - \frac{b_{\max} \cdot S(w) \cdot S(c)}{(A \cdot g_{б} + g_{bn})}.$$

The functions $S(w)$ и $S(c)$ - is single-factor dependence, having a form of dome-shaped curves that are well described by the equation of V.V. Shabanov [38]:

$$S(w) = \left(\frac{w_i}{w_{opt}}\right)^{\gamma \cdot w_{opt}} \left(\frac{w_{\max} - w_i}{w_{\max} - w_{opt}}\right)^{\gamma_w \cdot (w_{\max} - w_{opt})};$$

$$S(c) = \left(\frac{C_i}{C_{opt}}\right)^{\gamma \cdot C_{opt}} \left(\frac{C_{\max} - C_i}{C_{\max} - C_{opt}}\right)^{\gamma_c \cdot (C_{\max} - C_{opt})},$$

they are w_{opt} - an optimum value of water in the river; $w_{\max}$ - maximum volume of water in the river; w_i - factual value of the volume of water in the river; γ_w - self-parameter of plants in the aquatic environment; C_{opt} - the optimal value of contamination of river water; $C_{\max}$ - the maximum contamination of the river water; C_i - the actual value of contamination of river water; γ_c - self-parameter of plants in the polluted environment.

Thus, based on existing mathematical models of aquatic productivity we can define environmentally acceptable limits of human impact on the principle of Le Chatelier-Brown [37], which show that after any changes to elements of the natural environment (the material composition, energy, information, speed natural processes) is required to develop the chain reactions that try to neutralize these changes or the formation of new natural systems of education at which significant changes in the environment may become irreversible [37].

Discussion. Objective of research – the catchment basin of rivers of Karatal with 390 long km/s with an area of 19.1 thousand square kilometers, which is formed at the confluence of three rivers, called Tekly-aryk, Chadzha and Cora, the origins of which are located at an altitude of 3200-3900 m. are selected.

Starting 160 km is mountain character of the Jungar Alatau and below the confluence of Kara and Chizhe river enters the wide intermountain plain. Other tributaries are Kara, Terekty, Laba, Balykty, Mokur and most abounding Cox. After the confluence of the river inflow Koksu Karatal flows through the sandy desert of Southern Balkhash. At a distance of 40 km from the mouth of the river delta area is 860 km^2. According to long-term observations the average consumption of water in the river Karatal alignment Ushtobe is 66.7 m^3/s, or 2.1 km^3/year [36].

To observing the applicability of the range developed by modification of mathematical models for estimate the degree of environmentally acceptable water intake and wastewater discharge cities and industrial facilities, as well as the drainage water from irrigated lands hold a demo account with the following data Karatal river: the maximum volume of water in the river ($w_{\max}$) - 4.21 km^3; an optimum value of water in the river (w_{opt}) - 3.69 km^3; factual value of the volume of water in the river (w_i) - 2.28-4.21 km^3 ; the maximum concentration of the substance for plants in the river ($C_{\max}$) -0.5 g/liter; optimal for plants concentration of the substance in the river (C_{opt}) -0.25 g/liter; the actual concentration of the substance in the river (C_i) – 0.482 g/liter; self-parameter of plants (γ) -0.50 (given in table 3) [36].

According to Table 1 the graphics of functions $S(w)$ and $S(c)$, depending on the volumes of water and the pollution of water in rivers Karatal (figure 2) show that a characteristic feature of the curves is their dead-level.

This proves once again the assumption that the various securities for aquatic vegetation productivity are due to Karatal river water and the requirements to water conditions for maximum productivity of aquatic vegetation is phenotypic characteristic.

The second characteristic is that practically existing contamination of the water of the river Karatal still is the self-control of aquatic vegetation and therefore the range of acceptable values of contamination is located in the redistribution of inflection points, which in turn is fully determined by the position of the inflection points *S*(*c*).

Table 3 – The function meanings *S*(*w*) и *S*(*c*), depending on the volume of water and the pollution of water in rivers Karatal

w_i	*S*(*w*)	*S*(*c*)					
		C_i					
		0.00	0.10	0.20	0.30	0.40	0.50
		0.000	0.946	0.994	0.991	0.945	0.000
0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.50	0.090	0.000	0.085	0.089	0.082	0.085	0.000
1.00	0.144	0.000	0.136	0.143	0.143	0.136	0.000
1.50	0.291	0.000	0.275	0.289	0.288	0.275	0.000
2.00	0.470	0.000	0.444	0.467	0.466	0.444	0.000
2.50	0.664	0.000	0.609	0.660	0.605	0.608	0.000
3.00	0.850	0.000	0.804	0.845	0.842	0.803	0.000
3.50	0.982	0.000	0.929	0.976	0.973	0.928	0.000
4.00	0.916	0.000	0.866	0.910	0.908	0.865	0.000
4.21	0.000	0.000	0.000	0.000	0.000	0.000	0.000

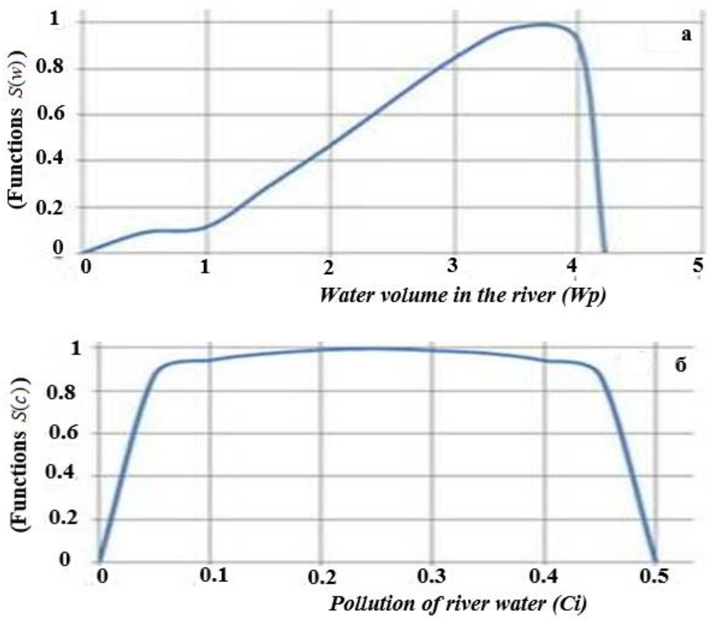

Figure 2 – Relative productivity of aquatic vegetation on the volumes of water (*a*) and pollution (*b*) of water in the river Karatal

As can be seen from table 3, it is possible to build a joint graph of the function $S(w)$ and $S(c)$, depending on the volume of water and the pollution of water in the river Karatal, allowing to estimate the extent of ecologically allowable water withdrawal from the river and discharge it polluted wastewater of cities and industrial facilities, as well as the drainage water with irrigated agricultural landscapes.

Conclusion. The natural river water is the vehicle for the redistribution of chemical elements between bio-geo-cenoces they are constant chemical reactions, that is, self-aquatic vegetation, which requires them to take into account when determining environmentally acceptable water abstraction and pollution of small river basin.

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КІШІГІРІМ ӨЗЕНДЕРГЕ ТҮСЕТІН ШЕКТЕЛГЕН-МҮМКІНШІЛІК ӘСЕРДІ ЭКОЛОГИЯЛЫҚ ТҰРҒЫДА БАҒАЛАУДЫҢ ӘДІСТЕМЕСІ

Аннотация. Су ортасы өнімділігінің қолданыстағы математикалық үлгілердің негізінде Ле-Шателье-Браун қағидасы бойынша антропогендік әсерінің экологиялық мүмкін шектерін анықтауға мүмкіндік беретін, тұрақты тепе-теңдік жағдайындағы су экожүйені сипаттайтын барлық табиғи және антропогендік ділелдемелерді ескеретін, су жүйесінің әрекетін бейнелейтін, өзен алабтарындағы заттардың гидрохимиялық балансының теңдеуі негізінде, математикалық үлгілердің модификациясының бірі жасалынды.

Түйін сөздер: үлгі, баға, қор, табиғат, өзен, су өтімі, ағын, қайтарма су, суды тұтыну, ланстану, функция, тұз, дәлелдеме.

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МЕТОДЫ ОЦЕНКИ ЭКОЛОГИЧЕСКИ ПРЕДЕЛЬНО-ДОПУСТИМОГО ВОЗДЕЙСТВИЯ НА МАЛЫЕ РЕКИ

Аннотация. На основе существующих математических моделей водной среды продуктивности позволяющих определить экологически допустимые пределы антропогенного воздействия на основе принципа Ле-Шателье-Брауна, разработана одна из модификаций математических моделей, на базе уравнения гидрохимического баланса вещества в речных бассейнах, описывающей поведение водной системы с учетом всех природных и антропогенных факторов, характеризующих поведение водной экосистемы, находящейся в состоянии устойчивого равновесия

Ключевые слова: модель, оценка, ресурсы, природа, река, расход воды, сток, возвратные воды, водопотребление, загрязнение, функция, соли, факторы.

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