- thorough considering regional strategies, taking into account regional peculiarities and priorities [1, 5, 17, 18, 19], expanding the scope of interregional cooperation [6];

- improvement of institutions of innovation development [1], innovation infrastructure [4, 6] and forms of organization of innovation activity [5];

- active involvement of universities into the processes of innovative development of regions [1, 20];

- support of small and medium-sized innovative entrepreneurship, development of a competitive environment [1, 6];

- increasing the level of well-being of the population to stimulate domestic demand for the final innovative product [15];

- creating an effective system for monitoring and evaluation of the implementation of innovative development strategies and programs, as well as scientific justification of corrective actions at all levels of management [6].

The implementation of these measures will allow for a much-needed structural shift in the national economy in favor of innovative sectors, an increase in the technological level of production, labor productivity and the standard of living of workers, a reduction in the country's import dependency in the high-tech sector and strengthening its international position.

References

1. E.M. Buchwald, The Bulletin of the Institute of Economics of the Russian Academy of Sciences, 4, 9-25 (2019) DOI: 10.24411/2073-6487-2019-10042

2. E.A. Tretiakova, ECO Journal, 46, 155-164 (2016) DOI: http://dx.doi.org/10.30680/ECO0131-7652-2016-12-155-164

3. Y.V. Vertakova, V.A. Plotnikov, Drukerovskij vestnik, 1, 5-20 (2020) DOI:10.17213/2312-6469-2020-1-5-20

4. A.G. Zeldner, V.S. Osipov, CITISE, 4, 560-570 (2020) DOI: http://doi.org/10.15350/2409-7616.2020.4.49

5. A.F. Sukhovey, I.M. Golova, Economy of region, 4, 1302-1317 (2020) https://doi.org/10.17059/-ekon.reg.2020-4-20

6. Yu.N. Yudenkov, Economic horizons, 2, 5-12 (2019)

7. Yu.A. Petrovskaja, I.V. Shchekina, World of Economics and Management, 3, 18-28 (2018) DOI 10.25205/2542-0429-2018-18-3-18-28

8. E. A. Kolomak., ECO Journal, 11, 121-128 (2016)

9. E. P. Kiselitsa, N. N. Shilova, I. A. Liman, Electronic Business Journal, 16, 96-109 (2017)

10. I.A. Rodionova, T.V. Kokuytseva, A.S. Semenov IJET, 7, 406-411 (2018) DOI: 10.14419/ijet.v7i4.38.24592

11. J. Fagerberg, M. Srholec, B. Verspagen, Review of Economics and Institutions, 1, 1-29 (2010) doi: 10.5202/rei.v1i2.2.

12. E.A. Tretyakova, A.A. Noskov, Balt. Reg., 1, 4-22 (2021) doi: 10.5922/2079-8555-2021-1-1

13. B.T. Kuznetsov, D.K. Balakhanova, Economics and management: problems, solutions, 3, 51-57 (2018)

14. K.V. Nazvanova, Economic Analysis: Theory and Practice, 2, 251-259 (2017) doi.org/10.24891/ea.16.2.251

15. K.K. Kolin, Strategic Priorities, 2, 66-91 (2019)

16 O. Golichenko, Voprosy Ekonomiki, 2, 97-108 (2017) https://doi.org/10.32609/0042-8736-2017-2-97-108

17. I.M. Golova et al., Economic Analysis: Theory and Practice, 5, 800-819 (2018)

18. S. A. Tumenova ISCFEC, 128, 2573-2579 (2020)

19. E. V. Rodionova, Z. O. Kuzminykh, ISPCBS, 90, 150-155 (2019)

20. A.A. Noskov, E.A. Tretyakova, Drukerovskij vestnik, 6, 163-182 (2017) DOI:10.17213/2312-6469-2017-6-163-182

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DYNAMICS OF AQUATIC RESOURCES CHANGE IN BELARUS IN MODERN CONDITIONS

Volchek A. A., Sidak S.V., Parthomuk S.I.

Abstract

The article addresses the main features of variability and dynamics of different river discharge in Belarus over 1948-2017. It has been found that for the 70-year period in question, the average annual discharge has slightly changed. The most significant changes are observed in the dynamics of the maximum spring discharge and the minimum winter discharge. The performed assessment of changes in the probability of extreme water flow rates of rare recurrence in the conditions of modern climate warming showed that the frequency of dangerous maximum and minimum water flow rates in 1988-2017 significantly decreased compared to 1948-1987.

Keywords: river discharge, long-term variability, intra-annual distribution, uniformity, cyclicity, trend.

Introduction. One of the priority areas of scientific research for –2021-2025 in the Republic of Belarus is the efficient use and management of water resources [1]. Recently, one of the priority tasks of effective nature management is the issue of preserving the quantity and quality of natural waters. A necessary and important condition for effective management of water use and protection is the availability of timely, reliable and complete information about water resources, their actual use and pollution due to wastewater discharge and other anthropogenic impact.

Global warming observed since the second half of the XX century has a great influence on the dynamics of river hydrology. The ongoing changes in river discharge affect the efficiency of the functioning of water resource systems of river basins, which determine the activities of many sectors of the economy (industry, hydropower, agriculture, fisheries), safety and living conditions of the population. Since the scale and nature of these changes are expressed in different manner for different river basins, the development of appropriate methods for assessing and taking into account the unsteadiness of river discharge characteristics and their practical testing requires the study of all major Belarusian rivers.

Analyzing the causes of discharge changes is very critical for environmental protection, economic development of the country and social stability. A significant discharge increase can lead to floods that seriously threaten life and property; a sudden discharge decrease can have a negative impact on biodiversity, shipping, irrigation, etc. Moreover, in the years of extreme drought, discharge changes are more sensitive to climate variability and human activity.

The purpose of this work is to assess the current changes in the average annual discharge, the maximum discharge of spring flooding, the minimum winter and minimum summer-autumn discharge of the Belarusian rivers.

Materials and methods. To study the long-term discharge variability involved data of hydrological observations of the average annual, maximum and minimum water consumption of the Belarusian rivers for the period of instrumental observations implemented by Republican Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus. Long-term changes in river discharge influenced by climatic factors and anthropogenic loads has been assessed for 6 hydrological posts of the largest rivers of Belarus: the Pripyat river, – city of Mozyr, the Neman river, – city of Grodno, the Western Dvina river, – city of Vitebsk, the Berezina river, – city of Bobruisk, the Dnieper river, – city of Orsha, the Dnieper river, – city of Rechitsa. The study period was 70 years (1948 to 2017). Gaps in data series were restored using "Hydrologist" computer software package [2].

The analysis of the long-term discharge variability was carried out in 4 stages:

– assessing the uniformity of the series of annual, maximum, minimum summer-autumn and winter discharge;

– estimating the discharge series cyclicity;

–analyzing the main trends in changes of all surveyed discharge types for the calculation period 1948-2017;

– assessing the changes of average annual, minimum, maximum river discharge for the period of 1988-2017 against 1948-1978.

The effective application of methods of mathematical statistics and probability theory to the series of hydrological characteristics requires assessing the time series adequacy to the required prerequisites of the mathematical apparatus used. The main requirements include the uniformity and stationarity of sampling, i.e. it is necessary that all random variables of the sample are from the same distribution of the general population, and the key sample parameters (the average, variance) are invariant in time [3].

The presence of discord points (years of deviating from observations uniformity) in hydrological time series, reflecting both changes in the behavior of discharge-forming factors and the discharge itself, is the main indicator of changes in the degree of impact of anthropogenic load and climate on the discharge formation process. In case of violation of the homogeneity and stationarity of hydrological time series, the previous calculations of the main hydrological characteristics become unreliable, resulting in changed of waterworks vulnerability, the inability to assess the risk of dangerous hydrological events, etc. In this regard, the detection of such points of discord should be considered as the very first and key step in analyzing the hydrological processes variability.

The idea of cyclic oscillations without the effect of shifting the boundaries between the phases of cycles of long and short duration, according to a number of researchers, provides the use of integral difference curves, or total curves [4]. To study the degree of synchronicity of long-term fluctuations of various types of discharge, integral-difference curves for the studied hydrological posts are built. The ordinates of the difference-integral curves are calculated as an increasing sum $Q_i \sum \frac{K_i - 1}{c_v}$, where Q_i is the modular coefficient, Q_i –is the river stream flow in the *i*-th year $\overline{Q}$ is the average annual value of the river stream flows, C_v is the discharge variation coefficient. The coefficient of variation is used in the formula to exclude the temporary influence of long-term discharge variability for subsequent comparison of long-term discharge fluctuations of different rivers.

The homogeneity of the discharge series was evaluated using five tests: Student, Fisher, Buishand, Pettitt, and the Standard Normal Homogeneity Test [5 –10].

The analysis of discharge trends was implemented in three stages. The first stage is to –identify the presence of a tendency to increase or decrease in discharge using the nonparametric Mann-Kendall criterion, the second step –is to estimate the magnitude or slope of a linear trend using a nonparametric estimate of Sen slope, the third stage is to –develop the discharge trend regression model. The Mann-Kendall test is *–a* rank test based on alternative measure of correlation known as the Kendall correlation coefficient [11]. Application of this test does not require a special form for the data distribution function, it is resistant to extreme values (i.e., highly distorted hydrological data) and deviations from linear dependence, but has a power almost as high as that of their parametric "competitors". The Mann-Kendall test is considered a reliable method for assessing trends, and is also recommended for use by the World Meteorological Organization. The limitations of this trend test are often associated with the null hypothesis (*H0*), which assumes that data are *independent andidentically-distributed, iid*. Therefore, from a strictly statistical point of view, the rejection of the *H0* hypothesis implies only the fact that the analyzed data set cannot be accepted as *iid*. Nevertheless, in practical applications, the refusal to accept the *H0* hypothesis is often considered as evidence of a trend in the surveyed hydrological series. In [12], it is proved that this latter is quite reasonable, since there is no (clear) trend in the *iid* datasets. The analysis of trend presence in the hydrological series $\{Q_i, i = 1, 2, ..., n\}$ using the Mann-Kendall test begins with statistic calculation:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(Q_j - Q_i), \quad (1)$$

where

$$\operatorname{sgn}(Q) = \begin{cases} 1, & Q > 0 \\ 0, & Q = 0 \\ -1, & Q < 0 \end{cases}. \quad (2)$$

The variance is calculated as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{g} \left(t_i (t_i - 1)(2t_i + 5)\right)}{18}, \quad (3)$$

where g is the –number of related groups, t_i –is the number of data values in the *i*-th group.

Standardized verification statistics *K* can be calculated by the formula:

$$K = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0 \end{cases}. \quad (4)$$

Positive values of statistics K indicate a tendency to increase, and negative values indicate –a tendency to decrease, in the surveyed characteristic. Standardized statistics K obey the law of a standard normal distribution with an average zero value and a unit variance. To assess the nature of the monotony of the trend at the significance level α , it is necessary to compare the value of statistics K with K (obtained from the standard table of normal distribution). If K , then the hypothesis *H0* deviates in favor of the alternative hypothesis *H1*, according to which the analyzed series has an increasing or decreasing trend.

In this study, Sen slope was used to assess the extent of changes in river discharge trends [13]. The Sen slope coefficient assessment has been recognized as "the most popular nonparametric technique for estimating a linear trend" [14]. This estimate is calculated using a simple nonparametric procedure as the median of the slopes of all possible ordered pairs of time values of the hydrological series. Sen slopes are more resistant to outliers than parametric tests such as linear regression, as they are calculated based on standardized data. It should also be noted that the presence of autocorrelation does not affect the estimated value of the Sen slope. The Sen method can be used in cases where it can be assumed that the trend is linear:

$$f(t) = \mu t + b, \quad (5)$$

where μ is the slope, b is the constant, t is the ordinal number of the observed value. To receive a slope estimation μ , the slopes of all pairs of data values are calculated first:

$$\mu_i = \frac{Q_j - Q_k}{j - k}, \quad (6)$$

where Q_j and Q_k are the data values at time *j* and *k* (*j*> *k*>), respectively. If there are *n* values in the time series Q_j Q_j , then there will be $N = n(n-1)/2$ $N = \frac{n(n-1)}{2}$ slope estimates μ_i . The Sen slope estimate – is the median of all N values μ_i .

$$\mu = \begin{cases} \mu_{\frac{N+1}{2}}, & N - нечетное \\ \dfrac{\mu_{\frac{N}{2}} + \mu_{\frac{N+2}{2}}}{2}, & N - четное \end{cases} . \tag{7}$$

To obtain an estimate b in equation (5), the n values of the differences are calculated $Q_i - \mu_{t_i}$. The median of these values gives an estimate b .

Results and discussion. Based on the results of checking the homogeneity of hydrological series according to the five proposed tests (Figure 1), the studied series are classified depending on the number of tests adopting the hypothesis of data homogeneity at the significance level of 5% based on the following:

- a data series belongs to *Class A* if the null hypothesis is accepted by all tests or rejected by one of five tests at a 5% significance level;
- a data series belongs to *Class B* if two or three tests reject the null hypothesis of data uniformity.;
- a data series belongs to *Class C* if four or five tests reject the null hypothesis of data uniformity at a 5% significance level.

As a result of checking the series of river discharge for uniformity, we came to the result: all surveyed series of maximum discharge belong to class C (points of discord in these series fall on the period of 1970-1988); the series of annual discharge for measuring stations of Pripyat river–city of Mozyr (with a discord point in 1968) and Dnieper river –city of Orsha (point of discord in 1984,) belongs to class B, the rest surveyed series of annual discharge belong to class A; a series of minimum winter discharge for measuring station of Neman river – city of Grodno belongs to B (with discord point in 1992), all other surveyed series of the minimal winter discharge belong to class C (points of discord in these series occur in the period 1969-1992); the series of minimal summer-autumn discharge for measuring stations of Berezina river – city of Bobruisk, Dnieper – Orsha, Pripyat – Mozyr, belong to class C, Dnieper –Rechitsa belongs to –class B, the rest belong to –class A.

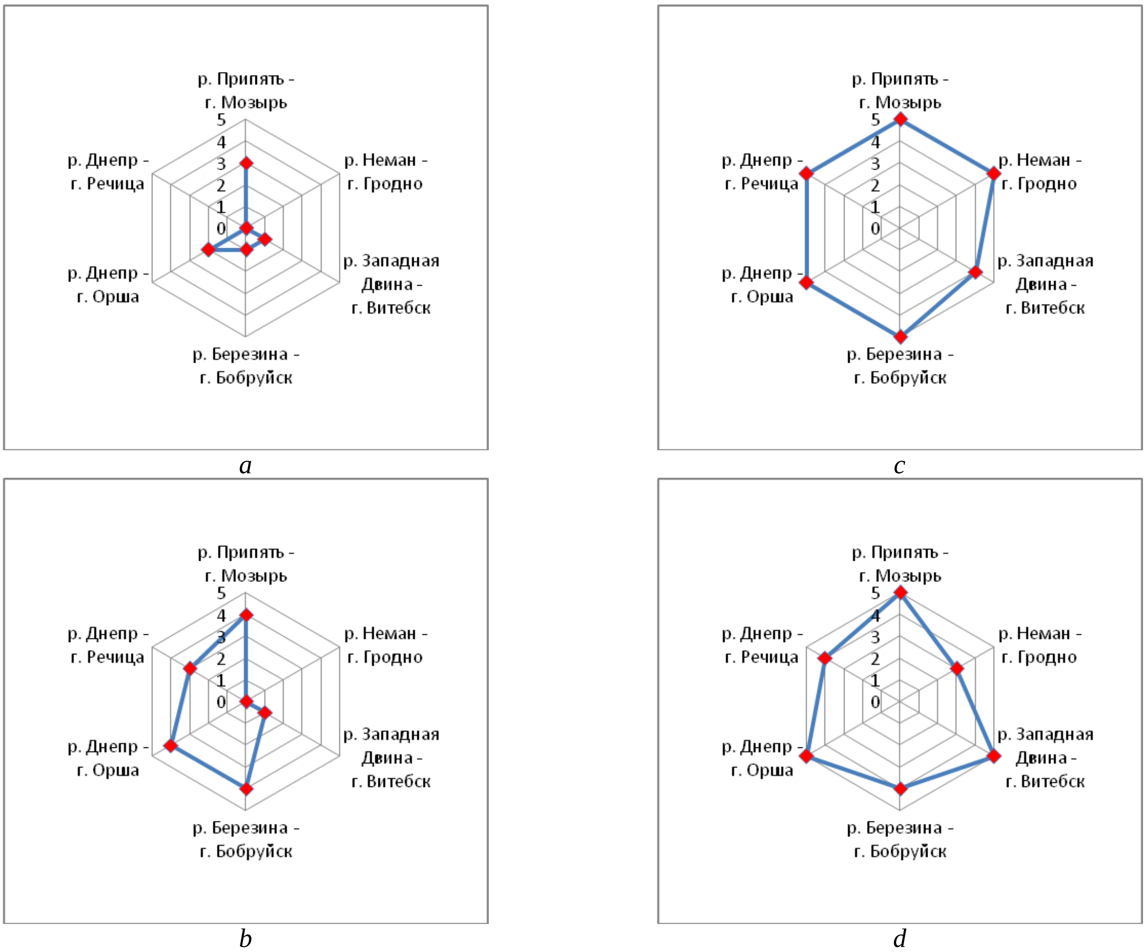

Figure 1 – The number of tests rejecting the null hypothesis of data uniformity for the series of average annual discharge (a), maximum discharge (b), minimum summer-autumn discharge (c), minimum winter discharge (d)

The results of studying cyclical long-term fluctuations of Belarusian rivers discharge are shown in Figure 2.

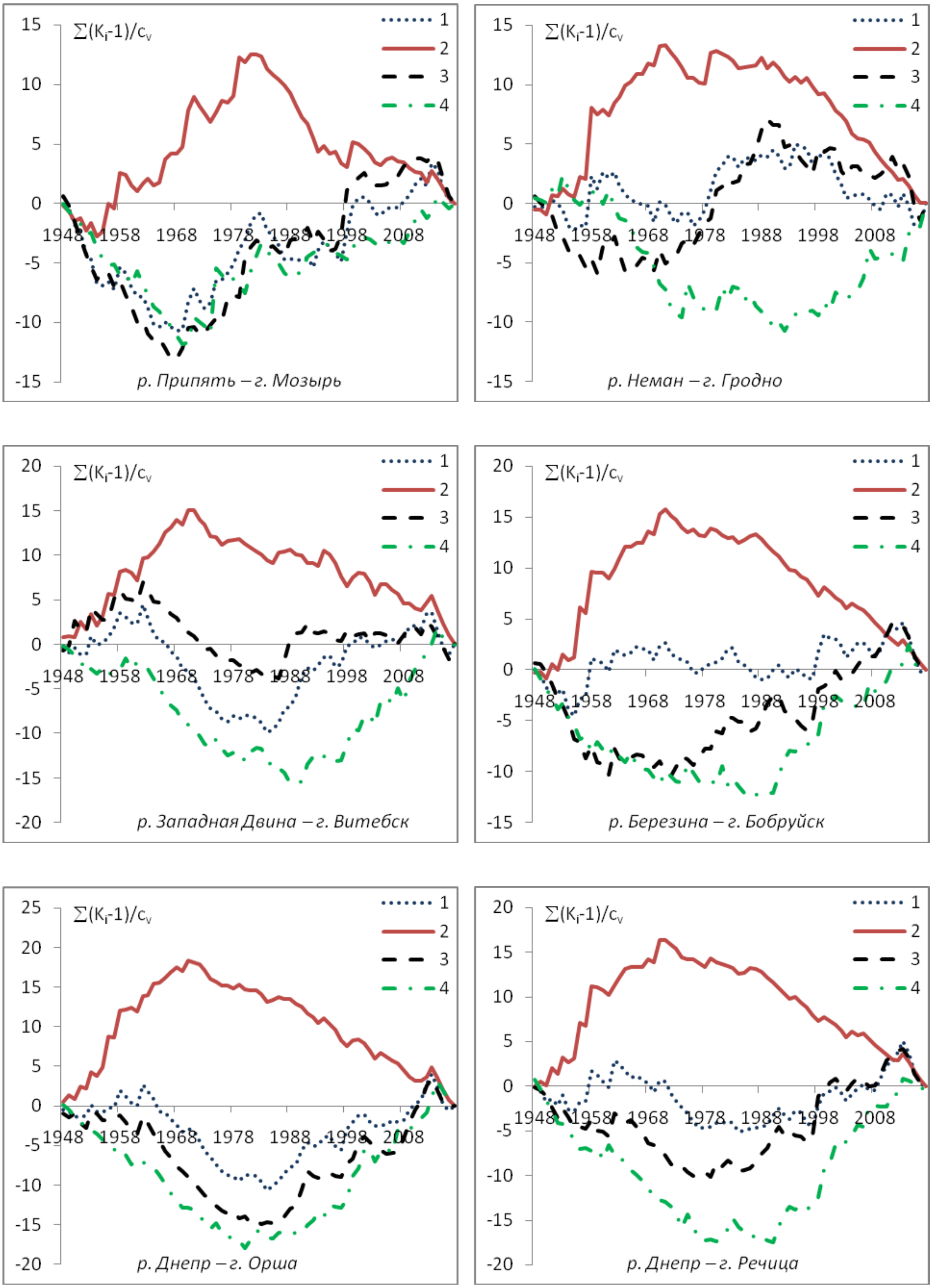

Figure 2 – Difference-integral curves of Belarusian rivers discharge:
1 – annual discharge, 2 – maximum discharge,
3 – minimum summer-autumn discharge, 4 – minimum winter discharge

Figure 2 shows that the long low-water phase in the long-term fluctuations of the annual, minimum summer-autumn and winter discharge observed on all the surveyed rivers since 1960, in the period from 1978 to –1987, replaced by a phase of increased water content. When analyzing the long-term dynamics of the maximum rivers discharge, it is possible to distinguish a high-water phase since 1948, which then was followed by a reduced water content observed until 2017 for all the surveyed rivers. The change of the water phase for the flows of the maximum discharge of Pripyat river at Mozyr measuring station, the Western Dvina River at Vitebsk measuring station, the Berezina river at Bobruisk measuring station occurred in 1971, for the Dnieper at Orsha and Rechitsa measuring stations, this date falls on 1970, for the Neman river at Grodno measuring station– for the period from 1971 to 1980. Therefore, for all the surveyed measuring stations during the study period (1948-2017), the predominance of low-water years is observed for the maximum discharge (46 out of 70). Almost all rivers demonstrate a clear asynchronous course in the long-term changes of the maximum and minimum discharge, maximum and annual discharge, which is confirmed by negative correlation values between the ordinates of the difference-integral curves of the corresponding stream flows (Table 1). For all rivers, significant correlations were obtained between the ordinates of the difference-integral curves of the minimum summer-autumn and winter discharge. For the Pripyat, Western Dvina, and Dnieper rivers, there is a clear phase synchronism in long-term fluctuations in annual and minimum discharge. It is worth noting that the shape of the difference-integral curves of the annual and minimum summer-autumn discharge of the Neman River at Grodno measuring station is somewhat different from the shape of the curves for these types of discharge for other studied measuring stations. The reason for such differences is the fact that in 1958 the Neman River experienced the highest flood in the last 150 years. This contributed significantly to the shape of difference-integral flow curves.

Table 1 – Correlation coefficients between ordinates of difference-integral curves of different types of discharge (1 –annual discharge, 2 –maximum discharge, 3 –minimum summer-autumn discharge, 4 –minimum winter discharge)

	2	3	4	2	3	4
	Pripyat – city of Mozyr			*Neman – city of Grodno*		
1	-0.05	0.95	0.87	0.50	0.66	-0.49
2		-0.17	-0.38		0.05	-0.71
3			0.85			-0.57
	Western Dvina – city of Vitebsk			*Berezina – city of Bobruisk*		
1	-0.51	0.81	0.77	0.18	0.31	0.20
2		-0.12	-0.68		-0.73	-0.90
3			0.52			0.80
	Dnieper – city of Orsha			*Dnieper – city of Rechitsa*		
1	-0.52	0.96	0.85	-0.36	0.72	0.74
2		-0.71	-0.83		-0.82	-0.86
3			0.94			0.88

Note. The highlighted values are statistically significant (at a significance level of 5%)

The results of assessing the trend of discharge series in Belarusian rivers using the Mann-Kendall test and Sen slope are shown in Figure 3 and in Table 2.

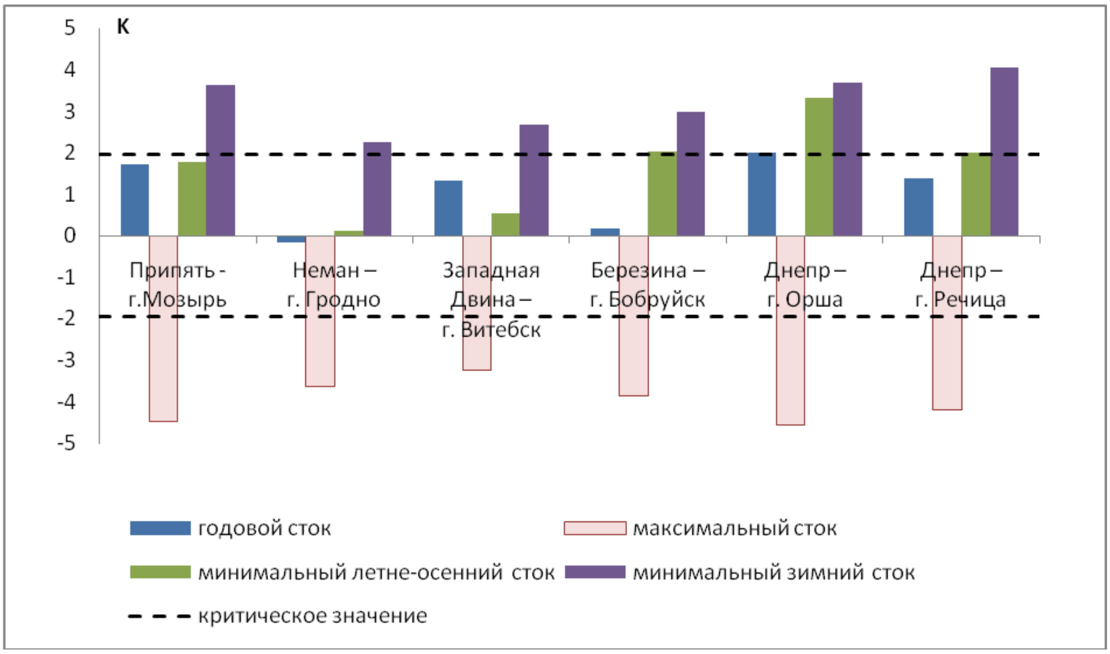

Figure 3 – Values of the verification statistics K for different types of discharge in the surveyed watersheds

Table 2 – Results of trend estimation using Sen method (regression equations)

River – Measuring station	*average annual discharge*	*maximum discharge*
Pripyat – Mozyr	$f = 1{,}32t + 341{,}47$	$f = -6{,}67t + 1367{,}33$
Neman – Grodno	$f = 0{,}01t + 184{,}00$	$f = -5{,}24t + 732{,}24$
Western Dvina – Vitebsk	$f = 0{,}50t + 204{,}25$	$f = -9{,}71t + 1634{,}71$
Berezina – Bobruisk	$f = 0{,}02t + 115{,}38$	$f = -4{,}66t + 523{,}91$
Dnieper – Orsha	$f = 0{,}37t + 109{,}33$	$f = -5{,}78t + 784{,}80$
Dnieper – Rechitsa	$f = 0{,}63t + 320{,}38$	$f = -11{,}33t + 1448{,}67$
	minimum summer-autumn discharge	*minimum winter discharge*
Pripyat – Mozyr	$f = 0{,}75t + 130{,}88$	$f = 1{,}59t + 108{,}75$
Neman – Grodno	$f = 0{,}01t + 88{,}03$	$f = 0{,}33t + 152{,}58$
Western Dvina – Vitebsk	$f = 0{,}05t + 46{,}06$	$f = 0{,}45t + 41{,}80$
Berezina – Bobruisk	$f = 0{,}16t + 49{,}40$	$f = 0{,}29t + 42{,}55$
Dnieper – Orsha	$f = 0{,}21t + 27{,}51$	$f = 0{,}34t + 24{,}38$
Dnieper – Rechitsa	$f = 0{,}45t + 137{,}77$	$f = 1{,}24t + 106{,}09$

Analysis of verification statistics K of the Mann-Kendall test enables to conclude that there is a statistically significant negative trend of the maximum discharge series, a statistically significant positive trend of the minimum winter discharge series for all surveyed measuring stations. Positive statistically insignificant trends are also observed for the series of average annual and minimum summer-autumn discharge.

The assessment of changes in the –probability of formation of extreme stream flows of rare repeatability in conditions of modern climate warming was implemented using the following criteria: to analyze changes in the repeatability of dangerous maximum stream flows, the number of years with an excess of 10% flow was selected, for the minimum summer-autumn and winter discharge, the number of years with a stream flow less than 90% flow. These thresholds were selected based on data analysis of the most significant floods and droughts on the Belarusian rivers [15, 16, 17]. To assess climate changes in connection with the recommendations of the World Meteorological Organization [18], as well as taking into account the fact that 1988 corresponds to the beginning of an intensive increase in average annual air temperatures in Belarus, the initial series was divided into two periods of 30 years or more: 1) from 1948 to 1987 and 2) from 1988 to 2017. Since the intervals under consideration have different lengths, we will present the repeatability estimate in the form of coefficients reflecting the intensity of extreme water flow rates of rare repeatability over a 10-year period. Table 3 shows the results of calculating such coefficients for two periods, respectively (1948-1987, 1988-2017).

Table 3 – Assessment of changes in the probability of formation of extreme water flow rates of rare repeatability

River – Measuring station	maximum discharge		minimum summer-autumn runoff		minimum winter discharge	
	1948-1987	1988-2017	1948-1987	1988-2017	1948-1987	1988-2017
Pripyat river – Mozyr	1.50	0.33	1.25	1.00	2.00	0.00
Neman river – Grodno	1.75	0.00	1.00	1.33	2.00	0.00
Western Dvina River – Vitebsk	1.50	0.33	0.75	1.67	1.25	1.00
Berezina river – Bobruisk	2.00	0.00	1.50	0.67	1.75	0.33
Dnieper river – Orsha	1.50	0.33	1.50	0.67	1.25	1.00
Dnieper river – Rechitsa	1.75	0.00	1.50	1.00	2.00	0.00

The results shown in Table 3 demonstrate that in the modern period, the frequency of dangerous maximum and minimum stream flows has significantly decreased for the studied measuring stations.

Table 4 shows data on statistical parameters of river discharge for 2 periods, confirming this result. Table 4 shows that all surveyed rivers experienced a significant decrease in maximum water flow (by 21-51%), an increase in minimum winter discharge (by 21-47%). A statistically insignificant decrease in the minimum summer-autumn discharge is observed for the Neman River at Grodno measuring station. Other surveyed stations are characterized by an increase in the minimum summer-autumn discharge (by 4 - 28%).

A significant decrease in the maximum discharge and an increase in the minimum winter discharge confirm the conclusion that the main feature of modern changes in the water regime of the Belarusian rivers is the discharge redistribution inside the year, emerging with a relative constancy of average annual water flows [18].

From the water use standpoint, reducing the maximum water flow of the spring flood entails ambiguous consequences. A positive aspect is the reduction of hydroecological risks and damage from floods, flooding of territories. A negative reaction is the possible formation of tension of water use in the low-water season. It should be noted, however, that reducing the maximum water flow of the spring flood does not exclude the possibility of the formation of major floods and, as a consequence, significant economic damage. Therefore, further study of extreme costs and taking into account their changes when performing hydrological calculations and forecasts of spring flood discharge are very important. This is very important not only in scientific, but also in applied terms, first of all, to prevent and reduce the negative consequences of both current and expected climate impacts, as well as to optimize economic activity in changing hydrological conditions.

Table 4 – Comparative assessment of the statistical parameters of the maximum and minimum discharge of the Belarusian rivers over two multi-year periods

River – Measuring station	Period	$\overline{Q}, \overline{Q},$ m^3/s	ΔQ, %	Average square deviation σ, (m^3/s)	/
	maximum discharge				
Pripyat river – Mozyr	1948-1987 1988-2017	1563 1043	-33	1017 623	0.61
Neman river – Grodno	1948-1987 1988-2017	789 477	-39	550 198	0.36
Western Dvina River – Vitebsk	1948-1987 1988-2017	1520 1202	-21	534 457	0.85
Berezina river – Bobruisk	1948-1987 1988-2017	594 290	-51	463 150	0.32
Dnieper river – Orsha	1948-1987 1988-2017	738 513	-30	306 196	0.64
Dnieper river – Rechitsa	1948-1987 1988-2017	1545 904	-41	979 380	0.39
	minimum summer-autumn discharge				
Pripyat river – Mozyr	1948-1987 1988-2017	156 175	12	71 71	0.99
Neman river – Grodno	1948-1987 1988-2017	91 86	-5	17 18	1.08
Western Dvina River – Vitebsk	1948-1987 1988-2017	52 54	4	22 19	0.86
Berezina river – Bobruisk	1948-1987 1988-2017	54 59	8	13 13	1.03
Dnieper river – Orsha	1948-1987 1988-2017	34 44	28	9 13	1.41
Dnieper river – Rechitsa	1948-1987 1988-2017	151 170	13	32 45	1.42
	minimum winter discharge				
Pripyat river – Mozyr	1948-1987 1988-2017	175 215	23	144 69	0.48
Neman river – Grodno	1948-1987 1988-2017	64 77	21	27 23	0.86
Western Dvina River – Vitebsk	1948-1987 1988-2017	50 73	46	19 31	1.62
Berezina river – Bobruisk	1948-1987 1988-2017	53 64	23	15 17	1.12
Dnieper river – Orsha	1948-1987 1988-2017	31 46	47	10 19	1.84
Dnieper river – Rechitsa	1948-1987 1988-2017	137 196	43	48 56	1.17

Conclusion. This study analyzes the long-term variability of annual, maximum, minimum summer-autumn and minimum winter water flow of large rivers of Belarus for the period of 1948-2017.

The study has provided with the following findings:

1. The heterogeneity in the time series of maximum and minimum winter water flow for all the studied measuring stations has been established. The points of discard in these series are mainly for the period of 1970-1988 .

2. For the majority of the surveyed rivers, an asynchronous course is clearly traced in the long-term changes in the maximum and minimum discharge, maximum and annual discharge.

3. Statistically significant negative trends have been established for the maximum series, significant positive trends –for the minimum winter discharge. The long-term trends of the annual and minimum summer-autumn discharge of the rivers of Belarus for the period of 1948-2017 demonstrate statistically insignificant (with the exception of the Dnieper, –Orsha measuring station) positive trends.

4. The frequency of extreme water flow of rare frequency has significantly decreased in the conditions of modern climate warming.

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References

1. О приоритетных направлениях научной, научно-технической и инновационной деятельности на 2021 – 2025 годы : указ Президента Республики Беларусь, 07 мая 2020 г., № 156 // Национальный реестр правовых актов Республики Беларусь. – 2020. – 1/18986.

2. Волчек, А. А. Автоматизация гидрологических расчетов / А. А. Волчек // Водохозяйственное строительство и охрана окружающей среды: Труды междунар. науч.-практ. конф. по проблемам водохозяйственного, промышленного и гражданского строительства и экономико-социальных преобразований в условиях рыночных отношений / Брест. политехн. институт. – Биберах– Брест–Ноттингем, 1998. – С. 55–59.

3. Сикан, А.В. Методы статистической обработки гидрометеорологической информации / А.В. Сикан.– Санкт Петербург, 2007. – 278 с.

4. Андреянов, В.Г. Циклические колебания годового стока и их учет при гидрологических расчетах / В.Г. Андреянов // Труды ГГИ. «Вопросы расчетов стока». Вып. 68; [под ред. А.И. Чеботарева]. Л.: Гидрометеоиздат, 1959. –С. 3–50.

5. Рекомендации по статистическим методам анализа однородности пространственно-временных колебаний речного стока. – Л. : Гидрометеоиздат, 1984. – 78 с.

6. Arun Kumar Taxak, A.R. Murumkar, D.S. Arya Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin, Central India // J. Weather and Climate Extremes. – 2014. – № 4. – P.50–61.

7. Buishand, T.A. Some methods for testing the homogeneity of rainfall records / T.A. Buishand // J. Hydrol. – 1982. – № 58. – P.11–27.

8. Alexandersson, H.A Homogeneity test applied to precipitation data / H.A. Alexandersson // Int. J. Climatol. – 1986. – № 6. – P.661–675.

9. Khaliq, M.N. On the critical values of the standard normal homogeneity test (SNHT) / M.N. Khaliq, T.B. Ouarda // Int. J.Climatol. – 2007. – № 27. – P.681–687.

10. Pettitt, A.N. A Non-Parametric Approach to the Change-Point Problem / A.N. Pettitt // Applied Statistics. – 1979. – № 28(2). – PP.126–135.

11. Nalley D, Adamowski J, Khalil B, Ozga-Zielinski B (2013) Trend detection in surface air temperature in Ontario and Quebec, Canada during 1967–2006 using the discrete wavelet transform. Atmos Res 132–133:375–398. doi:10.1016/j.atmosres.2013.06.011

12. Chandler, R.E.; Scott, M.E. Statistical methods for trend detection and analysis in the environmental analysis. Chichester: John Wiley and Sons, 2011.

13. Sen, P.K. (1968) On a Class of Aligned Rank Order Tests in Two-Way Layouts. TheAnnalsofMathematicalStatistics , 39, 1115-1124.

14. Руководство по гидрологической практике. Т. II. Глава 5. Анализ экстремальных значений. ВМО, 2012.

15. Волчек, А.А. Минимальный сток рек Беларуси: монография / А.А. Волчек, О.И. Грядунова ; Брест. гос. Ун-т имени А.С. Пушкина. – Брест : БрГУ, 2010. – 169 с.

16. Волчек, Ан.А. Затопления на территории Беларуси / Ан.А. Волчек // Вестник Брестского государственного технического университета. Серия: Водохозяйственное строительство, теплоэнергетика и геоэкология. – 2017. – № 2. – С. 39–53.

17. Логинов В.Ф. Весенние половодья на реках Беларуси: пространственно-временные колебания и прогноз / В.Ф. Логинов, А.А. Волчек, Ан.А. Волчек – Минск : Беларуская навука, 2014. – 244 с.

18. Volchak, Alexander. Intra-annual runoff distribution in the Pripyat River basin/ Alexander Volchak, Sergey Parfomuk, Svetlana Sidak // 2020 International Conference on Building Energy Conservation, Thermal Safety and Environmental Pollution Control (ICBTE 2020) / E3S Web Conf. Volume 212, 2020. – Brest, Belarus, October 29–30, 2020. https://doi.org/10.1051/e3sconf/202021201016.

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ANALYSING THE BELARUS POSITION IN THE INTERNATIONAL INNOVATION RANKINGS OF COUNTRIES AND STATE INNOVATION POLICY

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Introduction. The formation of a modern economic model in developed and rapidly developing countries is largely due to the increasing role of innovation and digital transformation. The place and role of Belarus in the global economy will largely be determined by its innovative development, the ability to build and effectively use own high-tech technologies, the degree of the country's presence in the international market of high and new technologies. Innovation is considered the main driver of economic growth, and innovation policy is an integral part of any country's economic policy. In modern realities, this is an objective condition for ensuring national security and sustainable development of the state.

The position of Belarus in innovation rankings

For the state, when determining the degree of its innovative development, its place in innovation rankings of other countries is very important. Such a comparative analysis with the leading developed and developing countries in the global economy as a whole enables to identify strong and weak sides of the country's innovative development and reveal factors constraining this development.