MINISTRY OF SCIENCE AND HIGHER EDUCATION
OF THE REPUBLIC OF KAZAKHSTAN

NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN UNDER THE PRESIDENT
OF THE REPUBLIC OF KAZAKHSTAN

National report on science

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The National Report on Science for 2022 contains an analysis of the state, trends and prospects of the development of the world and Kazakhstani science.

The National Report on Science defines the priority areas to be developed for scientific support of industrial-innovative development of the country; presents the main directions of development of Kazakhstani and world science; provides a detailed analysis of the situation in various spheres of science in the country; provides a comparative assessment of the state of science in the country and the world; reflects the scientific achievements of Kazakhstani scientists, the results of scientific activities of research institutes and higher educational institutions of the Republic of Kazakhstan, the results of scientific activities of research institutes and higher educational institutions of the Republic of Kazakhstan for 2022.

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the President of the Republic of Kazakhstan, 2023

1. INTRODUCTION
(the purpose of the National report)

The purpose of the annual National Science Report (hereinafter referred to as the Report) is to analyze the state of the main trends in the development of science, identify positive and negative factors affecting the development of Kazakhstani science, develop recommendations for further development and identify priority areas of its development.

Preparation of the Report is carried out by the Rules for the preparation of the annual National Report on Science, approved by the Decree of the President of the Republic of Kazakhstan dated August 21, 2012 № 369, and paragraph 3 of article 8 of the Law of the Republic of Kazakhstan «On Science».

The implementation of scientific research in 2022 was carried out by the 10 priorities of science development for 2022 approved at the meeting of the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan:

1. Rational use of water resources, animal and plant life, ecology;
2. Geology, mining and processing of minerals and hydrocarbon raw materials,

new materials, technologies, safe products and constructions. Research in geology, mining and processing of mineral raw materials;

3. Energy and mechanical engineering;
4. Information, communication and space technologies;
5. Scientific research in the field of natural sciences;
6. Life and health sciences;
7. Research in the field of education and science;
8. Research in the field of social sciences and humanities;
9. Sustainable development of the agro-industrial complex and safety of agricultural production;
10. National security and defense (unclassified).

The report is prepared on a three-year cycle, and each priority is divided into 3 parts. The depth of coverage of new scientific achievements published in highly rated domestic and foreign scientific journals and monographs is at least 3 years.

The analysis of the implementation of fundamental and applied research in priority areas of science (section #3) was performed by leading scientists working in the laboratories of research institutes and departments of higher educational institutions of the country.

The project managers for the ten science development priorities are:

Priority I – «Rational use of water resources, flora and fauna, ecology» – Ph.D., Associate Professor, Chairman of the Board of LLP «Kazakh Research Institute of Soil Science and Agrochemistry» named after U.Uspanov *Ramazanova R. H.*

Priority II – «Geology, mining and processing of minerals and hydrocarbon raw materials, new materials, technologies, safe products and constructions».

Section «New materials, technologies» – Ph.D., Associate Professor, head of the laboratory of Engineering profile of the NJSC «Kazakh National Research Technical University named after K. I. Satpayev» *Azat S.*

Priority III – «Power engineering and mechanical engineering», section «Mechanical Engineering» – Candidate of Technical Sciences, Professor of LLP «Eurasian Technological University» *Askarov E.S.*

Priority IV – «Information, Communication and Space Technologies» – Dr. Phys.-Math. Sc, professor of the Department of «Space Engineering and Technologies» of the Eurasian National University named after L. Gumilev. Kassymov U.T.

Priority V – «Research in the field of natural sciences», section «Fundamental research in the field of geography» – Ph.D in Geography, Associate Professor of UNESCO Department of Sustainable Development of Al-Farabi Kazakh National University *Pavlichenko L.M.*

Priority V – «Research in the field of natural sciences», section «Fundamental and applied research in the field of mathematics» - Dr. Phys.-Math. Sc, Professor, General Director of RSE «Institute of Mathematics and Mathematical Modeling» CS MSHE RK *Sadybekov M.A*.

Priority VI – «The Science of life and health» – PhD, Deputy Director of the Research Institute named after B.A. Atchabarov of KazMU named after S.D. Asfendiyarov *Fakhradiev I.R.*

Priority VII – «Research in the field of education and science» – Doctor of Pedagogical Sciences, Professor of the Department of Pedagogy and Methods of Primary Education of the NJSC «Kazakh National Pedagogical University» named after Abai *A. E. Zhumabayeva.*

*Priority VIII – «*Studies in the field of social sciences and humanities» – Candidate of Philological Sciences, Head of the Department of Philosophy of Al-Farabi Kazakh National University. *Kuranbek A. A.*

Priority IX – «Sustainable development of agro-industrial complex and safety of agricultural production» - Candidate of Physical and Mathematical Sciences, Vice-Rector for Science and Innovation of the Kazakh Agrotechnical Research University named after S.Seifullin *Tokbergenov I.T.*

Priority X – «National security and Defense» – Candidate of Military Sciences, professor of the RPA «Academy of Military Sciences» *Akshulakov K.Zh.*

Sections № 2,4,5,6 of the Report present:

– general characteristic of Kazakhstani science (with presentation of scientometric analysis for the last 3 years, analysis of achievements of Kazakhstani science (the most significant results of scientific and (or) scientific-technical activity, implemented developments), indicators of research activity of scientists (number of publications, citation index, impact factor of journals, patent activity);

– analysis of the state of scientific potential (qualitative composition of scientific organizations and higher educational institutions, autonomous educational organizations engaged in science, quality of training of domestic scientific personnel, attraction of foreign scientists, provision of scientific laboratories with modern equipment for scientific research);

– analysis of financing of scientific research and development (carried out from the state budget, attraction of financial resources to science from the private sector);

– analysis of global trends in the development of science (discoveries and achievements obtained by Kazakhstan science as a result of implementation of scientific and technical agreements with foreign and international scientific organizations).

The material was prepared under the scientific supervision of the President of JSC «National Center for State Scientific and Technical Expertise» of the Ministry of Education and Science of the Republic of Kazakhstan *A.K. Kashkinbekov.*

In addition, the expert group presented generalizations of the results of foresight research in 10 priority areas of science.

The expert commission was created, which included leading scientists in the branches of science who participated in discussing the works of authors and expert groups. The report is submitted to the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan.

2. GENERAL DESCRIPTION OF KAZAKHSTANI SCIENCE (with the presentation of scientometric analysis over the past 3 years, analysis of the achievements of Kazakhstani science (the most significant results of scientific and (or) science and technical activities, implemented products), indicators of research activity of scholars (number of publications, citation index, impact factor of journals, patent activity)

To assess the position of countries in critical key areas of the economy, international organizations regularly conduct studies on various indicators and indicators, from which a list of ratings and indices is compiled.

The Human Development Index (HDI) is a combined indicator that characterizes human development in countries and regions of the world. When calculating the HDI, 3 types of indicators are taken into account: life expectancy - which evaluates longevity; the level of literacy of the population of the country (average number of years spent on education) and the expected duration of education ; standard of living, estimated through gross national income per capita at purchasing power parity (PPP) in US dollars (table 2.1).

Table 2.1. The position of the Republic of Kazakhstan in the leading international rankings of scientific, technical and innovative development

	2020	2021	2022
Human Development Index	51st out of 189 countries	56th out of 191 countries (0.811 points)	56th out of 191 countries
Global Competitiveness Index	35th out of 64 countries	42nd out of 63 countries (35 points)	55th out of 63 countries
Global Innovation Index	79th out of 132 countries	83rd out of 132 countries (24,7 points)	83rd out of 132 countries

Source: https://gtmarket.ru/research/country-rankings

During 2021-2022, Kazakhstan remains in the group of countries with a very high level of human development, ranking 56th out of 191 countries that participated in the ranking, both among the member countries of the Eurasian Economic Union (EAEU) and among the CIS countries, where it ranked second, behind the Russian Federation.

Global Competitiveness Ranking. Under the competitiveness of the country is understood the ability of the national economy to create and maintain an environment in which there is a competitive business. The Industrial Competitiveness Index is calculated by the United Nations Industrial Development Organization (UNIDO) to 7 assess the level of competitiveness of the world's manufacturing industries. The index reflects the ability of countries to produce and export manufactured goods at a competitive level.

The business climate in the countries covered by this study is assessed based on the opinions of analysts, surveys of CEOs of large corporations and management professionals. The final rating is carried out on the basis of the inverse ratio: two-thirds - statistical data and one-third - expert assessments.

By this indicator, in 2022, Kazakhstan ranked 55th out of 63 countries. For the period from 2018 to 2022 - this is the lowest indicator. The best indicator for this period was in 2019 - 34th place.

Other EAEU or CIS countries did not participate in the ranking.

The Global Innovation Index (GII) ranks world economies according to their innovation performance. Consisting of about 80 indicators grouped by innovation inputs and outputs, the index considers various aspects of innovation. It is the most comprehensive index for assessing the level of scientific, technological and innovative development of the world's economies. The final index is a cost-benefit ratio, which objectively assesses efforts' effectiveness to promote innovation in a given country.

In 2022, Kazakhstan ranked 83rd out of 132 countries in the world ranking and 4th in the Central and South Asia region, behind Uzbekistan, which has 82nd and 3rd place, respectively.

At the end of 2022, the generalized indicator of GII for the Republic of Kazakhstan amounted to 24.7 points. Among the EAEU countries, the best indicators are the Russian Federation - 47th place with 34.3 points; the Republic of Belarus - 77th place with 27.5 points and Armenia - 80th place with 26.6 points.

The strategic goal of the Republic of Kazakhstan is the need to achieve high quality and sustainable economic growth by 2025, leading to an increase in the standard of living of people based on increasing the competitiveness of business and human capital, technological modernization, improving the institutional environment and minimal negative impact on nature, which is in line with the UN Sustainable Development Goals.

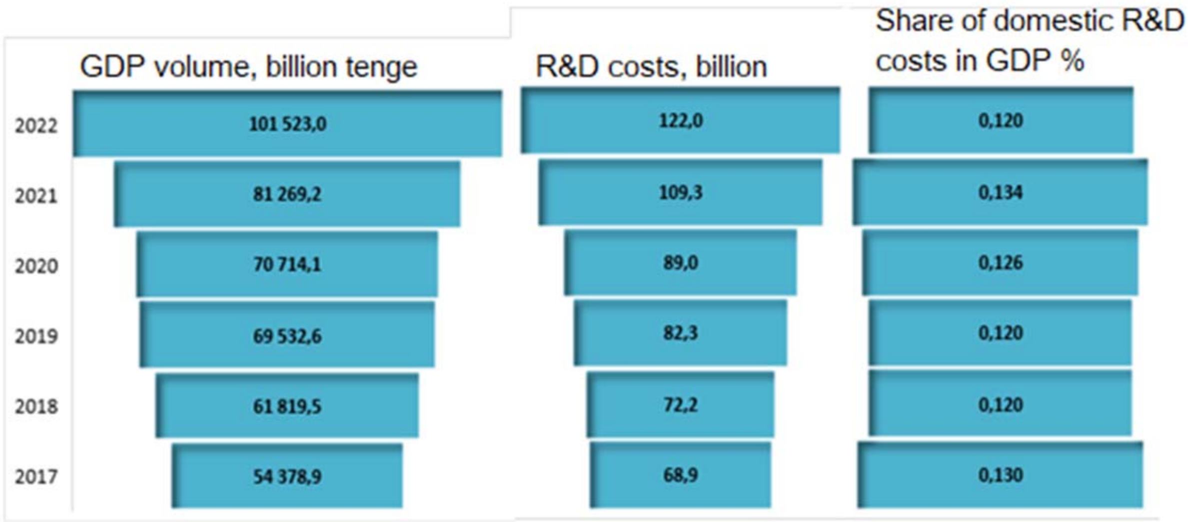
The Sustainable Development Goals (SDGs) are a call to action from all countries. Goal 9 calls on governments to create a sustainable infrastructure to promote industrialization and innovation by increasing spending on R&D and increasing the number of researchers.

According to the data, the top five countries with the highest spending on R&D include all major economies: the United States, followed by China, Japan, Germany, and the Republic of Korea. However, the ranking changes dramatically when viewed according to the indicator that should be used to monitor SDG 9 (R&D spending as a percentage of GDP). This indicator puts the Republic of Korea, the world leader, in first place, followed by Israel, Japan, Finland and Sweden.

However, R&D spending remains low in most countries of the world. Many regions, including Kazakhstan, set their own targets for R&D spending. Thus, in the Concept for the Development of Science of the Republic of Kazakhstan for 2023-2029, to increase the global competitiveness of Kazakhstani science and increase its contribution to solving applied problems at the national level, a gradual increase in R&D costs from all sources to 1% of GDP is provided.

It should be borne in mind that according to international standard definitions adopted in the economy of the Republic of Kazakhstan, domestic R&D expenditures are synonymous with R&D results.

In 2022, there is an increase in R&D spending in the Republic of Kazakhstan from 109,3 to 121,6 billion tenge. However, the increase in costs by more than 12 billion tenge did not affect the science intensity of GDP, which remained at 0,12% in the reporting year (fig. 2.1).



According to the data of the Bureau of National Statistics of ASPR RK

Figure 2.1. R&D expenditures

This is due, first of all, to the fact that the volume of the scientific product produced by scientists - new knowledge remains at a shallow level due to its low demand due to the fact that it is not brought to a state where this knowledge can be used in economic activities, in production. So, in 2022, research belonging to various degrees of theoretical development, i.e. basic and applied research, already accounted for 86% (82% in 2021) of expenditures.

Only 14% for R&D to create new materials, products, processes, devices, services, systems or methods and their further improvement. In such a situation, when there is no possibility of practical use of scientific achievements, it is tough to convince entrepreneurs of the necessity and usefulness of investments in science. In this regard, despite the increase in R&D expenditures, the science intensity of GDP has not changed in recent years, remaining at 0.12-0.13%.

An analysis of domestic R&D spending regarding funding sources shows that the state remains the main investor in scientific research in 2021. It accounts for almost 67% of expenditures, which is more than 7.4% in the previous year.

The volume of own funds, which can be considered as investments of entrepreneurs, tends to decrease annually. It stopped at 23% in 2022, down 10% from the previous year (table 2.2).

The contribution of other sources of investment in research activities does not exceed 9,5%. An indicator of the instability of research activities is the low percentage of borrowed bank funds - only 0.1%.

In general, information on the change in R&D expenditure by source of R&D funding is presented in figure 2.2.

Table 2.2. The volume of domestic expenditures on R&D by sources of financing

Sources of financing	2020		2021		2022	
	billion tenge	%	billion tenge	%	billion tenge	%
General costs	89,0	100	109,3	100	121,6	100
budget funds	45,6	51,2	63,6	53,6	81,5	67,0
own funds of scientific organizations	35,5	39,9	36,5	33,4	28,0	23,1
foreign investment	2,2	2,6	2,1	1,9	2,8	2,3
bank loans	0,1	0,1	0,04	0,1	0,1	0,1
other sources of funding	4,9	5,7	6,6	6,0	8,7	7,2

According to the Bureau of National Statistics ASPR RK

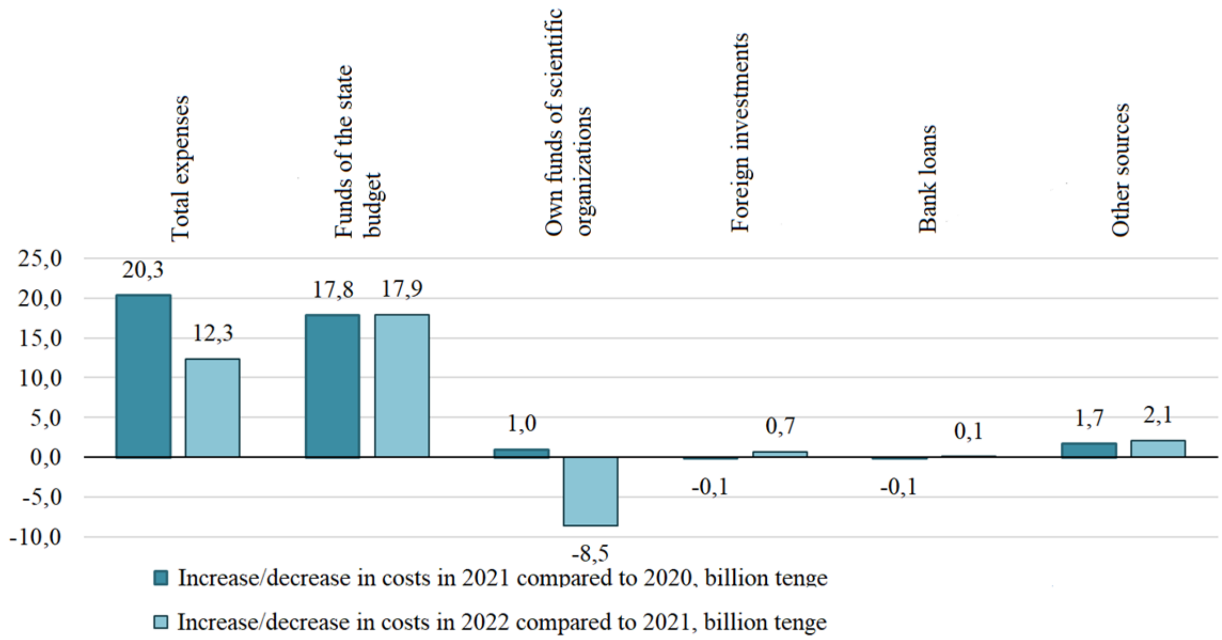


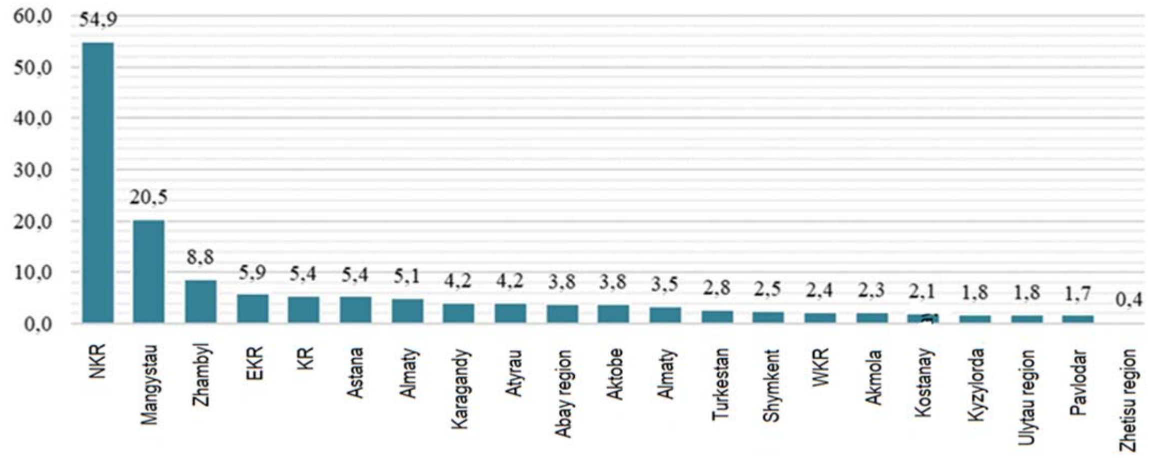
Figure 2.2. Dynamics of increase/decrease in R&D expenditures by funding sources for 2021-2022

In the regional context, the characteristics of its involvement in research activities are specific indicators of intensity, such as the volume of internal costs for R&D per employee and the number of employees who performed them per 10 thousand people employed in the economy (fig. 2.3).

The volume of costs per employee in 2022 on average in the country is 5.4 million tenge. The same level of costs is noted in Astana city. North-Kazakhstan, Mangistau, Zhambyl and East-Kazakhstan regions have the most significant volume of this indicator - 54.9; 20.5; 8.8 and 5.9 million tenge, respectively.

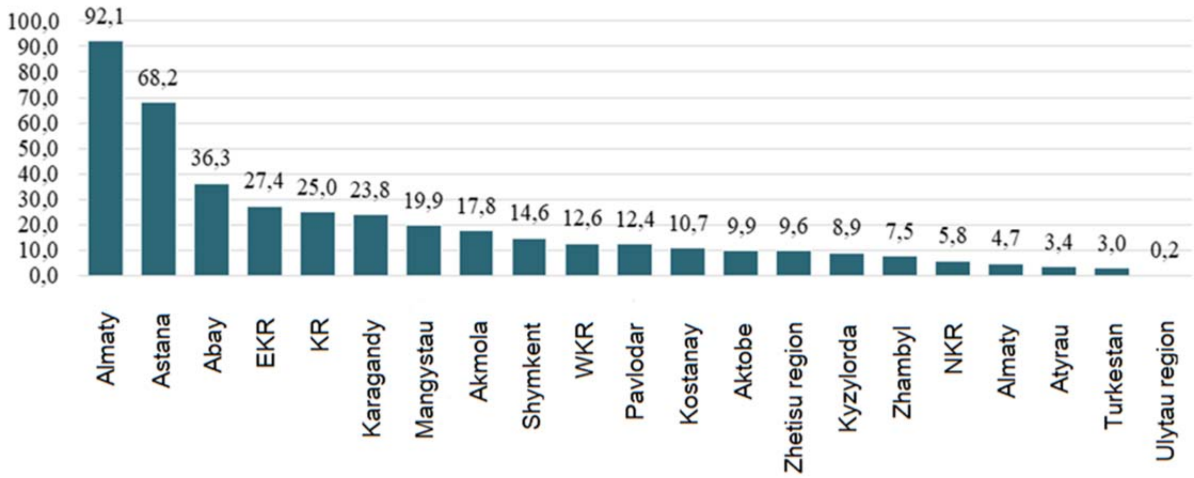
The lowest amount of costs is noted in the regions of Zhetisu, Pavlodar, Ulytau, Kyzylorda, where one employee accounts for from 0.4 to 1.8 million tenge.

According to the indicator «employees who performed R&D per 10 thousand people employed in the economy», the cities of Almaty (92,1), Astana (68,2), as well as Abay region (36,3). The outsider regions are Ulytau (0,2 persons per 10,000 people employed in the regional economy), Turkestan (3,0), Atyrau (3,4) и Almaty (4,7) (fig. 2.4).



Calculated according to the Bureau of National Statistics ASPR RK

Figure 2.3. Domestic R&D expenditures per employee engaged in research and development, mln tenge in 2022



Calculated according to the Bureau of National Statistics ASPR RK

Figure 2.4. R&D personnel per 10 thousand people employed in the economy in 2022

Innovative activity. The indicator characterizing the receptivity of the economy to innovations is the innovative activity of the organization/enterprises - it is a complex characteristic of the degree of intensity of actions to transform innovation into a new or improved product, technology, marketing or organizational service.

Innovative activity is the practical use of innovative, scientific and intellectual potential in mass production in order to obtain a new product that meets consumer demand in competitive goods and services

In 2022, the share of innovatively active organizations in the total number of organizations participating in the innovation activity survey amounted to 11,0%, which is 0,5 percentage point higher than last year's level (table. 2.3).

In general, in 2022, 3390 organizations out of 30,750 that participated in the study of innovative activity of organizations/enterprises were engaged in innovative activities.

Table 2.3. Leading indicators of innovative activity of enterprises of the Republic of Kazakhstan

Indicators	2020	2021	2022
Level of activity in the field of innovations, %	11,5	10,5	11,0
Total volume of innovative products (goods and services), billion tenge	1 715,5	1 438,7	1 879,1
Volume of sold innovative products (goods and services), billion tenge	1 664,6	1 318,1	1 739,8
The volume of sold innovative products (goods and services), delivered for export, billion tenge	308,0	214,5	286,3
The amount of costs for the implementation of innovations, billion tenge	783,3	800,1	1 453,3

According to the Bureau of National Statistics ASPR RK

Kazakhstani enterprises produced innovative products worth 1 879,1 billion tenge, which is 3,9% (3,4% – in 2021) of the total industrial production of goods and services for January-December of 2022. Compared to the previous year, there was an increase in the production of innovative products by more than 30%.

The total volume of innovative products sold amounted to 1 739,8 billion tenge, of which 286,3 billion tenge were exported. Innovation expenditures in 2022 amounted to more than 1 453,0 billion tenge, of which 7.6% accounted for public investment, however, this is 1,4 percentage points less than in the previous period (in 2021, public investment in innovation amounted to 9%).

Almost half of innovations (47,7%) were carried out at the expense of own funds, 37.7% were loans from banks, 1,4% - foreign investments, most of which (95,3%) were used in Kyzylorda region.

Innovation costs incurred by enterprises related to introducing new or improved goods accounted for 70,4%.

Almost 65% of total innovation expenditures were for purchasing machinery, equipment, software and other assets, 13% for R&D, and the remaining 22% for external knowledge acquisition, design, market research, training and other activities.

According to statistics, in 2022, 513 enterprises carried out the creation of innovations using R&D conducted within the enterprise, and 220 of them carried out research on an ongoing basis and 293 – occasionally, 203 enterprises reported that they acquired R&D conducted by third-party organizations to implement innovations.

Competitions of scientific projects/programs. In 2022, a total of 5 contests were announced for program-targeted financing of scientific, scientific and technical programs by the following departments: the Ministry of Education and Science of the Republic of Kazakhstan, the Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan, the Ministry of Industry and Infrastructure Development – 1 competition each; the Ministry of Trade and Integration – 2 (table 2.4).

Table 2.4. Information on competitions for program-targeted financing of scientific and scientific-technical programs announced in 2022

Science programs/projects administrator	SSTE			NSC	Implemen-tation period
	total filed	passed SSTE	trans-ferred to NSC	recommended /approved	
Program-targeted financing					
Ministry of Education and Science of the Republic of Kazakhstan	152	125	93	58	2022-2024
Ministry of Trade and Integration	5	5	3	3	2022-2024
Ministry of Labor and Social Protection of Population of the Republic of Kazakhstan	2	1	1	1	2022-2023
Ministry of Trade and Integration	3	2	1	1	2023-2025
Ministry of Industry and Infrastructure Development	1	1	1	1	2023-2025
Total	163	134	99	64	

Within the framework of competitions for program-targeted financing (PTF) the total number of applications submitted amounted to 163 units, of which 134 (82.2%) met the requirements of the tender documentation. They are aimed at conducting state scientific and technical expertise (SSTE).

According to the results of the SSTE, a threshold score was reached and an assessment of the validity of the amount of requested funding for 99 applications was received. Of these, 64 applications, or 64.6% of those submitted for consideration, were recommended for funding by the decisions of the National Scientific Council (NSC). The deadlines for the implementation of approved applications are 2022-2023, 2022-2024 and 2023-2025.

According to 8 competitions of the Ministry of Education and Science of the Republic of Kazakhstan, 7224 applications were submitted for grant financing (GF) for 2022-2024 and 2023-2025. After checking for compliance with the requirements of the tender documentation, 5,164 applications (71.5%) were admitted to the SSTE.

Of the **3369** applications that passed the SSTE and the assessment of the validity of the amount of requested funding, **1996** (52.3%) were approved by the decisions of the NSC (table 2.5).

In addition, JSC «Science Fund» announced a competition for grant financing of Results of Scientific and (or) Scientific-Technical Activity commercialization projects with an implementation period of 2022-2024. 152 applications were submitted for the competition, of which 134 (88.2%) passed the SSTE. 72 of the most promising projects, or 53.7% of the reviewed ones, received NSC approval for financing.

Grant financing of Results of Scientific and (or) Scientific-Technical Activity commercialization projects for 2020-2022 reached 11 876 million tenge: in 2020 – 5 400 million tenge, in 2021 – 4 860 million tenge, in 2022 – 1 616 million tenge.

Table 2.5. Information on grant funding competitions announced in 2022

Science programs/projects administrator	SSTE			NSC	Implementation period
	total submitted	passed SSTE	transferred to NSC	recommended /approved	
Grant financing of scientific and (or) scientific and technical projects					
Ministry of Education and Science of the Republic of Kazakhstan	772	609	382	137	2022-2024
Ministry of Education and Science of the Republic of Kazakhstan (for young scientists on the project («Zhas galym»)	176	120	74	70	2022-2024
Ministry of Education and Science of the Republic of Kazakhstan (for young scientists under the «Zhas Galym» project)	397	268	171	167	2022-2024
Ministry of Education and Science of the Republic of Kazakhstan (for young scientists under the «Zhas Galym» project)	289	217	117	106	2022-2024
Ministry of Education and Science of the Republic of Kazakhstan	2519	1902	1228	488	2022-2024
Ministry of Education and Science of the Republic of Kazakhstan (for young scientists under the «Zhas Galym» project)	503	330	173	120	2023-2025
Ministry of Education and Science of the Republic of Kazakhstan	453	295	225	130	2023-2025
Ministry of Education and Science of the Republic of Kazakhstan	2115	1423	999		2023-2025
Total	**7224**	**5164**	**3346**	**1996**	
Grant financing of projects for commercialization of the results of scientific and (or) scientific-technical activities					
JSC «Science Fund»	152	134	134	72	2022- 2024
TOTAL	**7539**	**5432**	**3504**	**2068**	

*New compositions of NNSs are approved by the order of the Ministry of Education and Science of the Republic of Kazakhstan dated June 5, 2023. The results will be submitted after the consideration of applications

Effectiveness of scientific, scientific-technical programs within the framework of program-targeted financing

In 2022, 132 programs were implemented within the framework of program-targeted financing: under the administration of the Ministry of Education and Science of the Republic of Kazakhstan (MES RK) – 59 units; Ministry of Agriculture of the Republic of Kazakhstan (MA RK) – 31; Ministry of Culture and Sports of the Republic of Kazakhstan (MCS RK) -13; Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan (MLSPP RK) – 2; Ministry of Health of the Republic of Kazakhstan (MH RK) - 9; Ministry of

Industry and Infrastructure Development of the Republic of Kazakhstan (MIID RK) – 1; Ministry of Digital Development, Innovation and Aerospace Industry of the Republic of Kazakhstan (MDDIAI RK) – 3; Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (MEGNR RK) – 7 Ministry of Energy of the Republic of Kazakhstan (ME) – 4; Ministry of Trade and Integration of Kazakhstan (MTI RK) – 3 units (table 2.6).

Table 2.6. General information on programs implemented within the framework of program-targeted financing, PCF 2022

Program Administrator	Implementation timeline	Number of programs, units	Share of applied R&D, %	Efficiency of publications, unit.						
				protection documents	total	foreign	Web of Science	Scopus	implemented	number of implementations
Competition programs of the PCF										
MA RK	2021-2023	27	100	52	493	146	14	56	11	74
	2021-2023	4	100	1	35	10	0	5	2	10
MIID RK	2022-2023	2	100	2	3	2	0	0	0	0
MCS RK	2020-2022	4	100	0	24	2	0	2	0	0
	2021-2023	9	100	0	67	12	2	2	1	1
MES RK	2021-2023	26	65,4	13	271	134	32	68	3	3
	2022-2023	6	50	0	60	23	5	8	0	0
MDDIAI RK	2021-2023	4	100	0	15	10	5	7	1	1
MH RK	2021-2023	5	100	2	77	46	4	11	4	54
MLSPP RK	2022-2024	1	100	0	12	8	0	0	0	0
MEGNR RK	2021-2023	7	100	7	122	41	6	12	3	20
ME RK	2021-2023	4	100	0	95	47	4	18	0	0
MTI RK	2022-2024	3	100	0	10	7	0	1	0	0
Total		***100***	***88***	***77***	***1284***	***488***	***72***	***190***	***25***	***163***
Non-competitive programs										
MIID RK	2020-2022	1	100	0	2	2	0	0	0	0
MES RK	2020-2022	1	100	0	3	2	2	0	0	0
	2021-2022	20	60	20	571	154	42	71	7	28
	2021-2023	6	33,3	0	199	30	7	24	0	0
MDDIAI RK	2020-2022	1	100	3	7	7	7	7	0	0
MH RK	2020-2022	2	50	0	23	17	13	13	1	8
MLSPP RK	2021-2023	1	100	*4*	43	32	0	1	1	*4*
Total		***32***	***59,4***	***23***	***848***	***244***	***71***	***116***	***9***	***37***

Within the framework of competitions, 100 programs were implemented, and out of competition - 32 with implementation periods 2020-2022, 2021-2022, 2021-2023, 2022-2024.

Of the 132 programs implemented in 2022, 18.9% (25 units) are fundamental and 81.1% (107 units) are of applied nature. Applied programs significantly prevail in the framework of competitions - 88%, while in non-competitive programs, their share is less than 60%.

According to the reports registered with JSC NCSTE, the research was carried out in 10 priority areas of science development approved by HSTC: Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technology, safe products and structures (GDPMTIK); Information, communication and space Technologies and Information, Telecommunication and Space Technologies (ICST); Research in education and science (RSE); Research in the social sciences and humanities (ISSH); Life and Health Sciences (LHS); Scientific research in the field of natural sciences (SRNS); Scientific foundations of «Mangilik el» (education of the XXI century, fundamental and applied research in the field of humanities) (Mangilik el); National Security and Defense (NS&D); Rational use of water resources, flora and fauna, ecology (RIPR); Rational use of natural resources, flora and fauna, ecology (RIPR); Sustainable development of the agro-industrial complex and the safety of agricultural products (AIC); Energy and mechanical engineering (E&M). The results of implementing programs in the context of priorities are presented in table 2.7.

Table 2.7. Results of the implementation of competitive and non-competitive programs in the context of priorities, PCF 2022

Priority	Total programs, units.	Efficiency of publications, unit.							
		protection documents	Publications				implemented	number of implementations
			total	foreign	Web of Science	Scopus		
AIC	31	53	528	156	14	61	13	84
RSSH	28	1	681	151	4	33	4	11
LaHS	17	5	135	76	19	29	7	65
NS	13	18	229	129	60	71	3	5
RUoWR	11	7	124	49	3	12	3	20
ITST	9	4	89	64	17	42	4	15
GMPMHRM	7	9	56	19	9	16	0	0
EME	7	3	116	60	13	31	0	0
Mangilik El	4	0	24	2	0	2	0	0
RiEaS	3	0	145	22	2	9	0	0
NSaD	1	0	3	2	2	0	0	0
RUoNS	1	0	2	2	0	0	0	0
Total	132	100	2132	732	143	306	34	200

In general, during the implementation of competitive and non-competitive programs of program-targeted financing for 2022, 100 protection documents were received, 2132 scientific papers were published, of which 732 or more than 34.3% are presented in foreign publications, including 143 in Web of Science and 306 in Scopus. The results of 34 research projects (25.8%) have implementations, which was 200 units.

The efficiency of scientific, scientific-technical projects of grant financing

In 2022, within the framework of 10 grant financing competitions held by the Ministry of Education and Science of the Republic of Kazakhstan and the Ministry of Digital Development, Innovation and Aerospace Industry, **1961** projects were implemented, of which **493** with a completion date in the current year and **1468** ongoing research projects with implementation dates in 2021-2023, 2022-2024. Fundamental research prevails in the projects being implemented – 51.2%, in completed research there is a slight excess of applied works – 50.7% (table 2.8).

Table 2.8. General information on projects implemented under grant financing, GF, 2022

Project Administrator	Implementation period	Number of projects, units	Share of applied research, %	Efficiency of publications, unit.						
				protection documents	Publications				implemented	Number of implemetations
					total	fo-reign	including Web of Science	including Scopus		
Ongoing projects										
MSHE RK (for young scientists)	2021-2023	151	53	21	381	194	70	103	2	2
MSHE RK	2021-2023	383	49,3	43	1560	640	171	328	30	58
MSHE (for young scientists)	2022-2024	135	44,4	4	114	45	13	19	1	2
MSHE RK	2022-2024	471	48,6	2	318	113	16	38	4	4
MSHE RK project «Young scientist»	2022-2024	69	47,8	2	52	13	2	7	2	2
MSHE RK project «Young scientist»	2022-2024	159	39,6	2	47	10	2	4	1	1
MSHE RK project «Young scientist»	2022-2024	100	53	0	18	8	3	3	0	0
Total		***1468***	***48,2***	***74***	***2490***	***1023***	***277***	***502***	***40***	***69***
Completed projects										
MSHE RK (GF for young scientists)	2020-2022	163	58,9	49	716	324	115	205	31	42
MSHE RK (implementation period 27 months)	2020-2022	325	45,8	94	1792	868	342	552	53	112
MDDIAI RK	2020-2022	5	100	7	34	18	1	12	0	0
Total		***493***	***50,7***	***150***	***2542***	***1210***	***458***	***769***	***84***	***154***

According to the reports registered with NCSTE JSC, the research was carried out in 12 priority areas of science development indicated above, as well as in the priority « Information, telecommunications and space technologies, scientific research in the field of natural sciences» (SRNS) (table 2.9).

During their implementation in 2022, 224 protection documents were received, 5032 scientific papers were published, of which 2233 or more than 44% are presented in foreign publications, including 735 in Web of Science and 1271 in Scopus. The results of 124 research works (6.3%) have been implemented, which amounted to 223 units.

Table 2.9. Results of ongoing and completed grant financing projects by priority, GF, 2022

Priority	Number of projects	Protection documents		Efficiency of publications, units				implemented		number of implementations	
		unit	for 1 project	total	for 1 project	including foreign	for 1 project	unit	for 1 project	unit	for 1 project
AIC	107	19	0,18	237	2,2	96	0,9	13	0,12	18	0,17
GMPMHRM	248	21	0,08	215	0,9	113	0,5	0	0,00	0	0,00
NS	306	37	0,12	791	2,6	492	1,6	8	0,03	18	0,06
ITST	130	11	0,08	348	2,7	218	1,7	9	0,07	14	0,11
RiEaS	111	3	0,03	288	2,6	103	0,9	12	0,11	25	0,23
RSSH	270	3	0,01	875	3,2	207	0,8	14	0,05	22	0,08
SRNS	35	5	0,14	129	3,7	53	1,5	1	0,03	1	0,03
Mangilik El	115	2	0,02	960	8,3	271	2,4	29	0,25	53	0,46
NSaD	33	8	0,24	91	2,8	28	0,8	2	0,06	5	0,15
LaHS	218	12	0,06	235	1,1	134	0,6	10	0,05	30	0,14
RUoWR	98	6	0,06	116	1,2	58	0,6	1	0,01	1	0,01
RUoNS	107	56	0,52	405	3,8	247	2,3	18	0,17	24	0,22
EME	183	41	0,22	342	1,9	213	1,2	7	0,04	12	0,07
Total	**1961**	**224**	**0,11**	**5032**	**2,6**	**2233**	**1,1**	**124**	**0,06**	**223**	**0,11**

Thus, in 2022, 132 programs were implemented under the administration of 10 ministries - 100 under 13 competitions and 32 under 7 non-competitive applications. Under 10 competitions for grant funding, 1961 projects were implemented, of which 493 were completed and the remaining 1468 were ongoing R&D.

The result of the implementation of research in 2022 within the framework of program-targeted and grant funding were: 324 protection documents; 7164 publications, of which 2965 – in foreign publications, including 878 – in Web of Science and 1577 – in Scopus; 423 implementation certificates were received for 158 implementations.

2.1 Analysis of Kazakhstan science achievements (significant results of scientific and (or) scientific-technical activity, implemented developments)

Implemented developments are selected based on the results of final R&D reports of scientific and scientific-technical programs and projects completed in 2022 that scored 30-34 points on the SSTE.

According to scientific research in the field of Life and Health Sciences, the National Center for Biotechnology has developed:

1. Cryobiotechnology for the conservation and reproduction of rare and endangered plant species, molecular genetic methods have been introduced to determine the species belonging of rare and endangered species of the fauna of Kazakhstan. The result of the research is the creation of an electronic database of a

biobank with open access for viewing, containing passport data of DNA samples and biological materials of rare and endangered species of flora and fauna of Kazakhstan (Southern, Western, East Kazakhstan, Akmola, Karaganda, Almaty regions). The program «Creation of a biobank of rare and endangered species of flora and fauna of Kazakhstan for the conservation of biodiversity»;

2. Heparin-conjugated fibrin hydrogel (HCFH) containing autologous mesenchymal stem cells of the synovial membrane and growth factors to stimulate cartilage tissue regeneration. A minimally invasive method of HCFH implantation in the knee joint was proposed. This new drug and innovative method were studied for safety and efficacy of use on patients with osteoarthritis of the knee joint and introduced into clinical practice. Program «Introduction of Innovative Tissue Engineering Technologies into Medical Practice for Restoration of Damaged Joints».

In the field of natural sciences:

1. The Institute of Plant Biology and Biotechnology has developed biotechnological approaches based on DNA technologies for an effective system of monitoring, identification and prevention of the most dangerous diseases of agricultural crops. Program «Development and implementation of highly effective diagnostic systems for identification of the most dangerous diseases and increasing the genetic potential of crop resistance»;

2. Scientists of the Institute of Genetics and Physiology have developed informative methods of analysis, selected effective ways of diagnostics and treatment of a number of socially significant diseases, created new medicines and technologies aimed at improving the human environment and quality of life. Program «Development and application of new genomic technologies to protect organisms from mutagenic influence, increase the productivity of natural resources and improve the population's quality of life»;

3. Employees of the Mangyshlak experimental botanical garden revealed biological regularities of plant acclimatization in different soil and climatic conditions of introduction areas, created an effective system of biodiversity conservation in arid and mountainous conditions. Effective technologies of propagation of promising plants for rational use in the practice of green building, horticulture and phytomelioration were introduced. A decorative, exposition and park zone has been created on the plots of «Zarechye Eco-Land» LLP using varietal flower plants and tree and shrub introducers. The program «Development of scientific and practical foundations and innovative approaches to plant introduction in natural areas of Western and Eastern Kazakhstan for rational and effective use».

In the field of information technology at the Institute of Mechanics and Machine Science named after U.A. Dzholdasbekov, a robotic complex with the introduction of 6 intelligent control structures has been proposed, which allows to completely eliminates the contact of medical workers with patients and reduces the risk of their infection. The robotic complex makes it possible to solve the important problem of acute shortage of medical staff and optimally redistribute the load on regular employees, freeing up staff for other important tasks. The program «Development and implementation of medical robots and intelligent systems in Kazakhstan to improve the system of diagnosis and treatment of patients in pandemic conditions».

In the energy field, scientists of the Almaty University of Power Engineering and communications named after G. Daukeev have introduced intelligent algorithms and new control devices for intelligent power systems. The results of the project can be used to solve the problems of planning and operation of electric networks, optimize the operation of electric networks and to improve the integration of non-traditional environmentally friendly energy sources (solar panels and wind generators) into the general electric grid of the Republic of Kazakhstan. The results of the work are already being used at the site of the electric networks of JSC «Alatau Zharyk Companiyasy». This direction is important for the development and implementation both in the Republic of Kazakhstan and on a global scale.The project «Optimization of planning and management of electrical modes in Smart Grid systems».

In the field of sustainable development of the agro-industrial complex and the safety of agricultural products, the Kazakh Agrotechnical University named after S.Seifullin has developed and implemented a model of technology for creating a raw material conveyor that provides a year-round solid fodder base for small cattle in the northern region of Kazakhstan. The raw material conveyor for the production of coarse, juicy and concentrated fodder will reduce the cost of livestock products by increasing the productivity of dairy goats and reduce the cost of transportation and purchase of fodder from other farms and regions by creating its solid fodder base. The system of year-round provision of animals with fodder will increase the competitiveness of livestock production and will provide additional income for agricultural producers in Kazakhstan. The project «Development of a raw material conveyor for the year-round provision of full-fledged fodder for dairy goats in the conditions of the arid steppe of the Akmola region».

In the field of rational use of natural resources, Kazakh National Research Technical University named after K.I. Satpayev has developed:

1. Innovative methods for forecasting and assessing the state of rock masses, ensuring industrial and environmental safety during subsoil development. Based on the results of tests at the Central quarry of the Akzhal deposit, the method of strengthening the quarry slope and the composition of the solution for strengthening mountain ranges were accepted for implementation. Ground and underground permanent centering points of the devices have been accepted for practical use in geodetic monitoring at the Akzhal field. The project « Development of innovative methods for forecasting and assessing the state of the rock mass for the prevention of man-made emergencies».

2. Technology of deep purification of gases from SO_2 and NO_x with further utilization of CO_2 by electrolysis of the Li_2CO_3 melt at 900ºC. The annual economic effect from the introduction of electrolysis technology for the utilization

of CO_2 from waste gases was calculated. The use of the developed technology in practice allows us to solve the problem of creating highly effective and economically feasible sanitary purification of waste gases from TPPs, power plants and metallurgical plants from SO_2, NO_x and CO_2 with the production of marketable products (elemental sulfur and/or sulfuric acid and biofuel) in the conditions of Kazakhstan and abroad. The project «Development of a new high-tech technology for utilizing SO_2 and CO_2 from waste gases of TPPs and metallurgical enterprises to obtain marketable products».

The significant results of scientific and (or) scientific and technical activities include the works of domestic scientists noted in accordance with the Order of the Minister of Education and Science of the Republic of Kazakhstan dated December 28, 2022 № 216 «On awarding nominal prizes in the field of science and state scientific scholarships in 2022»:

For the best scientific research:

- in the field of natural sciences, Kazakh scientists prof. Insepov Z.Z. (USA, head of the Anchor Project of the international level of Nazarbayev University), prof. Tynyshtykbaev K.B. (Kazakhstan, employee of the International Anchor Project of NU), Dr. Baigarin K.A. (RK, Advisor to the President of NU) were awarded the prize named after. K.I. Satpayev. Their work on the topic «Threshold-free amplification of acoustic wave surfaces» , carried out at Nazarbayev University by an international scientific group consisting of scientists from Kazakhstan, the USA and Russia, opens up new possibilities for the use of modern promising material – graphene – in micro- and nanoelectronics. The results of the study demonstrated the possibility of amplifying high-frequency acoustic signals with graphene, which is currently the strongest, thinnest and ultra-light electrically conductive material in the world, at negligible energy costs. Practical developments arising from this discovery are of significant value to international companies operating in the defense industry, medicine, national security, and space communications;

- Scientists of Al-Farabi Kazakh National University Khokhlov S.A. and Ibraimov M.K. were awarded the prize named after D.A. Kunaev among young scientists in the field of natural sciences. The theme of their project is «Development of new methods of neural network analysis and computer modeling for solving problems of astrophysics and electronics»;

- in the field of humanities, professor of Kazakh National Pedagogical University named after Abai Ishpekbayev Zh.E was awarded the prize named after Shokan Ualikhanov. His monograph «Mangilik el kazagyna khat» consists of four chapters. The first chapter covers a long period from the beginning of the history of the Kazakh people to 1917. The second chapter is a difficult period from the October Revolution of 1917, which created a special breakthrough for the Kazakh people, to the moment of independence in 1991. The third chapter shows the achievements and shortcomings of the Kazakh society, features, relations of the titular nation with other representatives of the diaspora. In the final fourth chapter, the author tries to answer the question of what the youth of Kazakhstan should be like if high dreams of yesterday and today become the reality of life tomorrow. It is shown that the function of national education and national public consciousness is always high in the development of civilization. The author is proud of the achievements of the country and, revealing some of the existing problems, gives specific recommendations;

- In the field of Turkology, Prof. Absadyk A.A. of Kostanay State University is named after. A. Baitursynov was awarded the Kul-Tegin Prize. He conducted comprehensive research on the educational and teaching activities of A.Baitursynov - «Akhmet Baitursynulynyn agartushy ustazdyk kyzmeti»;

- in the field of pedagogy, head of the department of legal disciplines at the «Kainar Academy», assoc. prof. Apakhaev N.Zh. was awarded the prize named after Y. Altynsarin for the textbook « Kazakhstan Respublikasynnyn enbek kukygy» (Okulyk), which covers issues of labor law of the Republic of Kazakhstan;

- in the field of humanities on the topic «Organizational behavior», the Prize of M.O. Auezov was awarded to A.T. Omarova, Karaganda State University named after Academician E.A. Buketova.

The achievements of Kazakhstani science also include domestic highly cited publications created without foreign co-authorship. These are 5 works of Kazakh scientists that aroused active interest in the scientific community and were in the top 1% in the world citation ranking for 2020-2022.

In the field of environmental sciences and ecology, the article «Assessing air quality changes in large cities during COVID-19 lockdowns» remains relevant: The impacts of traffic-free urban conditions in Almaty, Kazakhstan» , presented by scientists A. Kerimray, N. Baymatova, O. Ibragimova, B. Bukenov, B. Kenesov from the Center for Physico-Chemical Methods of Research and Analysis of Al-Farabi Kazakh National University, P. Plotitsyn from Airkaz.org , which tracks air pollution, and F. Karadja from Nazarbayev University. The work is devoted to assessing changes in air quality in large cities, in particular Almaty, during the quarantine of COVID-19. The analysis of the impact of blocking from March 19 to April 14, 2020 on the concentration of air pollutants in Almaty was carried out. The results demonstrate the influence of road traffic on the complex nature of air pollution, which is largely facilitated by various sources unrelated to road traffic. These are mainly coal-fired thermal power plants and domestic heating systems, as well as possible small irregular sources, such as garbage incineration and baths. The article was published in the journal «Science of the Total Environment» with an impact factor of 7.963, quartile Q1 in the category of Environmental Sciences.

The next most cited work in the field of engineering «Speech emotion recognition with deep convolutional neural networks» was prepared by scientists Issa D., Demirci M.F. and Yazici A. from Nazarbayev University. It is dedicated to speech emotion recognition using deep convolutional neural networks. The most effective model based on experimental results is proposed, surpassing the existing platforms for RAVDESS and IEMOCAP, thereby establishing a new level of technology and favorably differing in terms of generality, simplicity and applicability. The results of the study are presented in the journal «Biomedical Signal Processing and Control» with an impact factor of 2020 - 3.88, quartile Q2 in the categories of Engineering, Biomedical.

The following is the article «Corporate Social Responsibility Strategy and Corporate Environmental and Social Performance: The Moderating Role of Board Gender Diversity» in the field of economics and business by scientists from KIMEP and the Higher School of Economics and Business of Al-Farabi KazNU Orazalina N. and Baydauletov M. Based on the theories of the highest echelons of power and dependence on resources, and using data from European listed companies for the period 2009-2016, they examined the impact of corporate social responsibility (CSR) strategy and gender diversity of boards of directors on environmental and social performance. The work was presented in the journal Corporate Social Responsibility and Environmental Management with an impact factor of 8.741, quartile Q1 in the Business category.

In the field of chemistry, high interest was shown in the «Review of COVID-19 testing and diagnostic methods» , prepared by scientists O. Filchakova, D. Dosym, A. Ilyas, T. Kuanysheva, A. Abdizhamil and R. Bukasov from Nazarbayev University.

The work provides a review of testing and diagnostic methods for COVID-19. Methods for detecting COVID-19 are described, analyzed and compared, presenting their parameters in 22 tables. The performance of some FDA-approved test kits was compared with the clinical performance of some non-FDA-approved methods just described in the scientific literature. The need for alternative, less expensive and faster methods of detecting and treating the virus at the point of care has been demonstrated. The review was presented in the journal «Talanta» with an impact factor of 6.556, quartile Q1 in the Chemistry, Analytical category.

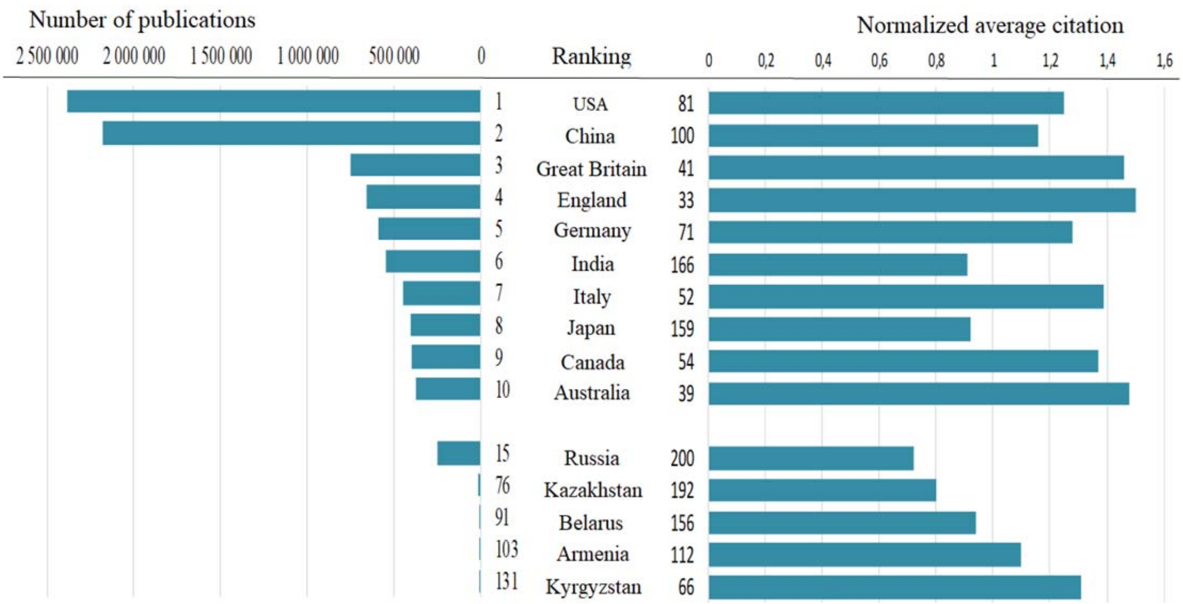
In the field of social sciences, the group of highly cited ones included an article by L. Karabasova from Nazarbayev University «Teachers conceptualization of content and language integrated learning (CLIL): evidence from a trilingual context», which shows teachers’ perceptions of content and language integrated learning (CLIL). Kazakhstan is the first country in Central Asia to introduce CLIL to use three different languages as a medium of instruction in different subjects as part of an ambitious national policy on languages in education. Findings from studies on the conceptualization of CLIL from teachers' perspectives indicated that the majority of participating teachers were unaware of the pedagogical intentions behind CLIL and understood it simply as teaching in another language. Subject teachers who worked in the context of a complex inquiry-based curriculum prioritized content over language, assuming only an indirect role in facilitating students' language development. The work appears in the International Journal of Bilingual Education and Bilingualism with an impact factor of 3.165, quartile Q2 in the Education & Educational Research category.

2.2. Indicators of research activity of scientists

An important component of science is the exchange of information, ideas, and experimental results. For this purpose, various forms of research publications are used: reports, monographs, dissertations, etc. A prerequisite for conducting scientific activity is the publication of scientific articles, the main purpose of which is to communicate promptly the results of scientific research to the public. It is the number of printed works that is an indicator of scientific productivity [1,2].

Both the quantity and the quality of publications are widely spread scientometric indicators worldwide. Based on the citation data of scientific materials included in the database of scientific information, various scientometric indicators are calculated, which can help both scientists and managers in daily practice and are the basis for identifying the achievements of participants in the scientific process – authors, organizations, regions and the country as a whole.

According to InCites, the number of publications in Kazakhstan for 2020-2022 amounted to 12536 documents, which allowed the country to take 76th place in the world ranking out of 213 countries according to this indicator (figure 2.5).



According to InCites (Clarivate Analytics), as of 23.05.2023.

Figure 2.5. Ratings of countries by the number of publications and normalized citation for 2020-2022

The figure shows the top 10 countries that occupy leading positions in the world ranking in terms of the number of publications. These are the USA, China, Great Britain, etc., as well as Kazakhstan's partner countries in the Eurasian Economic Union (EAEU), which were distributed as follows: Russia - 15th place; Belarus – 91; Armenia – 103; Kyrgyzstan – 131.

The normalized average citation is an indicator of scientific effectiveness. It is calculated as the ratio of the number of references to an article to the total number of articles of the same type published in this subject area in the same year. If the value obtained is more significant than one, then the study is cited better than expected and is highly appreciated in the world, if less than one, the popularity of the article is low, it is cited worse than articles on this topic [3].

In the ranking for this indicator for 2020-2022, equal to 0.80, Kazakhstan ranks only 192nd.

In the first group of countries, England has the highest level of this criterion – 1.50; Australia – 1.48 and Great Britain – 1.46, which provided them with 33, 39 and 41 places in the ranking, respectively.

Of the EAEU countries, only Kyrgyzstan traditionally ranks 66th with a small number of publications, having a normalized average citation of 1.31. Armenia, Belarus and Russia were placed in 112, 156 and 200 places, respectively.

The Journal Impact Factor is considered an essential characteristic and indicator of the importance of a scientific journal in Scientometrics.

Scientific works of Kazakhstan for 2020-2022 are presented in 3743 publications, including 3227 journals, of which 2285 (61.0%) have an impact factor (table 2.10).

Table 2.10. Distribution of journals with Kazakhstani publications by the value of their impact factor

Journal rating*	Measurement range of impact factor	Number of magazines	Number of articles
Very high	above 10	133	356
High	>5 – 10	462	1521
Average	>1 – 5	1440	4363
Low	>0,5 – 1	198	632
Very low	>0 – 0,5	52	132
–	no impact factor	942	4268
Total:		3227	11272

* Classification scale of ratings of scientific journals included in the Journal Citation Reports (Clarivate Analytics)

According to InCites (Clarivate Analytics), as of 05.23.2023

The number of articles published in journals in 2020-2022 is 11272 in total, including 7004 (62.1%) in publications with impact factor.

The number of publications indexed in 2020-2022 includes 17 Kazakhstani journals with a total number of articles - 1397 units. Their citation rate is low, exceeding 50% only in two journals, the founders and publishers of which are Eurasian National University named after L.N. Gumilev and the Institute of Metallurgy and Ore Beneficiation - these are Eurasian Mathematical Journal and Kompleksnoe Ispolzovanie Mineralnogo Syra. For the first time 12 out of 17 journals indexed during the study period have an impact factor for 2022 (table 2.11).

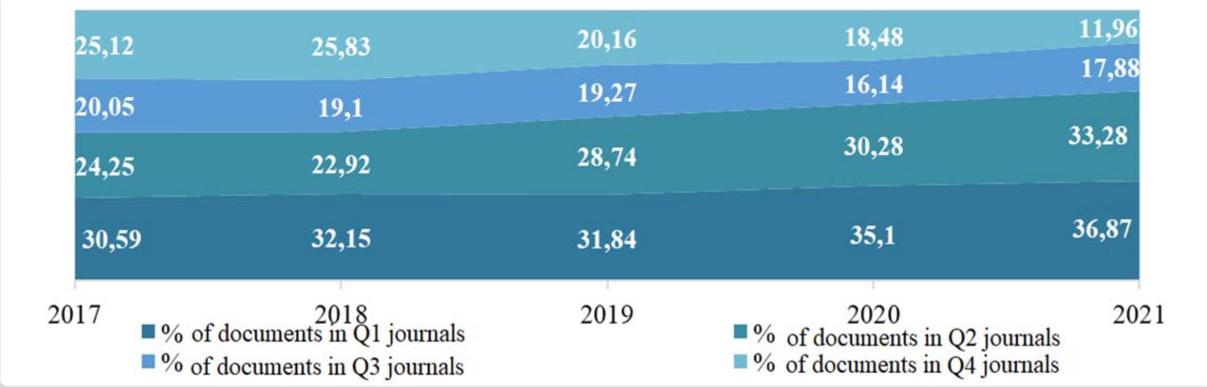
It should be noted that in 2022, only 11 Kazakhstani journals were included in the Emerging Sources Citation Index database.

To assess the popularity and influence of a journal, it is better to use not the absolute value of its impact factor, but its place within the ranked list of the impact factor of journals, divided into four quartiles. The share of Kazakhstani articles by quartile of Journal Citation Reports is shown in figure 2.6.

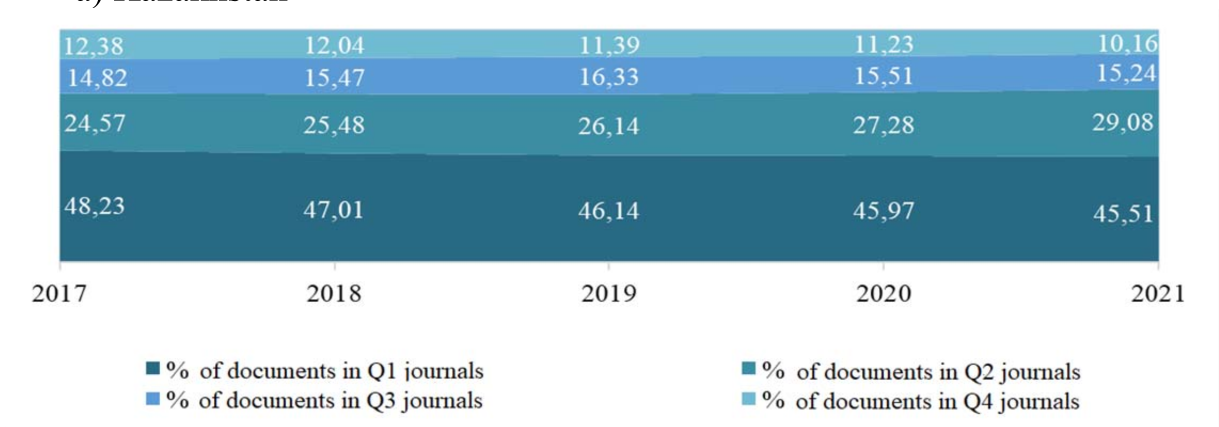
Table 2.11. Kazakhstani journals included in the Emerging Sources Citation Index

Name of publication	Number of articles	Share of cited articles, %	Normalized average citation	Impact factor for 2022	Publisher
*Bulletin of the National Academy of Sciences of the Republic of Kazakhstan	155	20,65	0,05	–	NAS RK
Journal of Mathematics Mechanics and Computer Science	128	11,72	0,06	0,1	KazNU
Kompleksnoe Ispolzovanie Mineralnogo Syra	123	54,47	0,28	0,7	IMOB
Bulletin of the University of Karaganda - Chemistry	121	31,40	0,09	0,5	KarSU
Bulletin of the Karaganda University - Mathematics	115	37,39	0,38	0,6	KarSU
Recent Contributions to Physics	108	4,63	0,01	0,1	KazNU
*News of The National Academy of Sciences of The Republic of Kazakhstan-Series Chemistry and Technology	102	18,63	0,02	-	NAS RK
Bulletin of the University of Karaganda - Physics	101	23,76	0,08	0,4	KarSU
*News of the National Academy of Sciences of the Republic of Kazakhstan - Series Physico-Mathematical	100	14,00	0,02	-	NAS RK
*News of the National Academy of Sciences of the Republic of Kazakhstan - Series of Geology and Technical Sciences	95	27,37	0,06	-	NAS RK
Eurasian Chemico-Technological Journal	63	30,16	0,07	0,5	IAG
*International Journal of Biology and Chemistry	57	28,07	0,06	0,3	KazNU
Chemical Bulletin of Kazakh National University	52	25,00	0,06	0,3	KazNU
International Journal of Mathematics and Physics	32	15,62	0,03	<0,1	KazNU
Eurasian Mathematical Journal	31	70,97	1,05	1,0	ENU
Eurasian Journal of Mathematical and Computer Applications	12	41,67	0,19	0,5	ENU
*Central Asian Journal of Global Health	2	50,00	0,05	-	NU; University of Pittsburgh
Total	1397	26,06	0,12	-	-

*Publications that are not updated in the Emerging Sources Citation Index in 2022
According to InCites (Clarivate Analytics), as of 05.23.2023



a) Kazakhstan



b) the world corps

According to InCites (Clarivate Analytics), as of 05.23.2023

Figure 2.6. Dynamics of articles in quartiles of journals by impact factor

As can be seen from the presented data, the share of articles in prestigious Q1 and Q2 journals in 2021 was over 70%, which is 15.3% higher than in 2017. At the same time, in the world corps, a slight decrease in the share of papers in Q1 and Q4 journals is evident, with a simultaneous increase in Q2 journals.

For 2020-2022, the share of Kazakhstani publications in the flow of scientific information in the Web of Science Core Collection database is at the same level with an average value over three years - 0.12% (table 2.12).

The publication array of Kazakhstan for 2020-2022 is affiliated with 125 Kazakhstani organizations, of which universities - 71, research institutes - 50, public organizations - 4. More than 90% of scientific papers or 10993 publications were prepared with the participation of researchers from universities.

Table 2.12. Share of Kazakhstani publications for 2020-2022 in the world flow of scientific papers

Years	Number of publications		Share of Kazakhstani publications to the world, %
	Kazakhstan	world corps	
2020	4 528	3 535 074	0,13
2021	3 997	3 623 007	0,11
2022	4 011	3 356 005	0,12
2020-2022	12 536	10 514 086	0,12

According to InCites (Clarivate Analytics), as of 5.23.2023.

Since publication activity is one of the leading indicators of the performance of scientific work, quantitative analysis of scientific papers can provide insight into the performance of scientific organizations as a whole.

According to the number of publications in the Web of Science Core Collection, the leading positions are held by Nazarbaev University (2960 docs.), Kazakh National University named after Al-Farabi (2563) and Eurasian National University named after L.N. Gumilev (1131 docs.) (fig. 2.7).

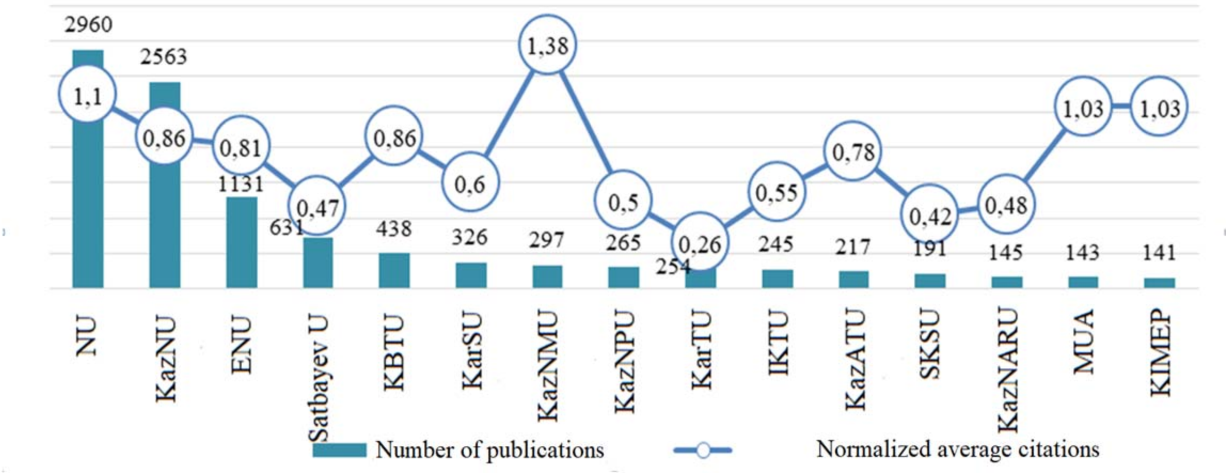
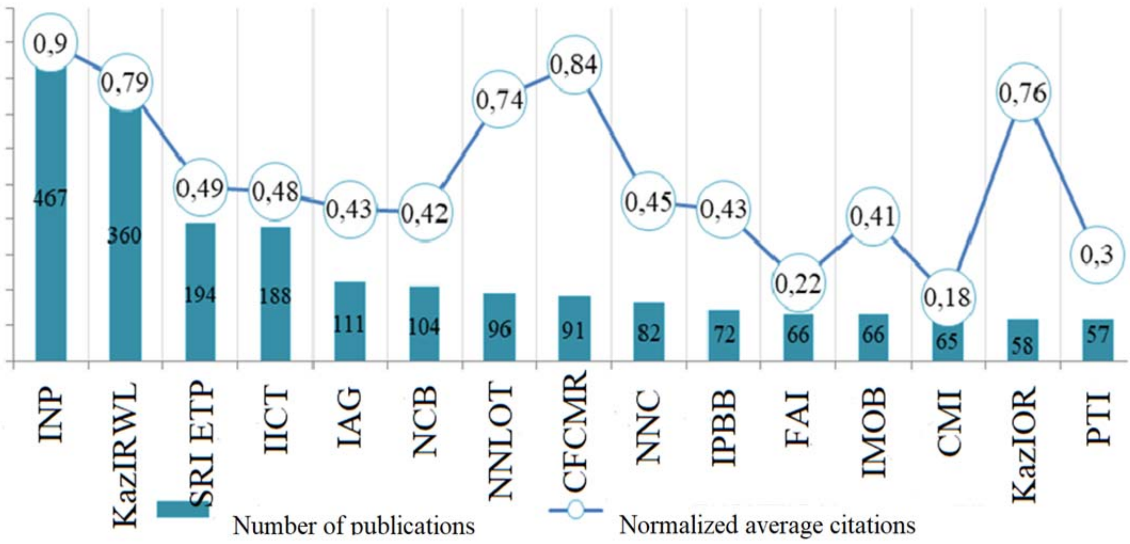


Figure 2.7. Bibliometric indicators of Kazakhstan universities, top-15

Among the research institutes, the leaders are the Institute of Nuclear Physics (467 doc.), the Institute of Mathematics and Mathematical Modeling (360), the Institute of Experimental and Theoretical Physics (194) and the Institute of Information and Computing Technologies (188 doc.) (fig. 2.8).



According to InCites (Clarivate Analytics), as of 23.05.2023
Figure 2.8. Bibliometric indicators of Kazakhstani research institutes, top-15

According to the normalized average citation index (scientific effectiveness), the leader among the studied universities is the Kazakh National Medical University named after S.D. Asfendiyarov. The value of the indicator is 1.4 times higher than the world average and is 1.38. This indicator is slightly higher than one at Nazarbaev University (1.10), KIMEP and Astana (AMU) Universities – 1.03 each.

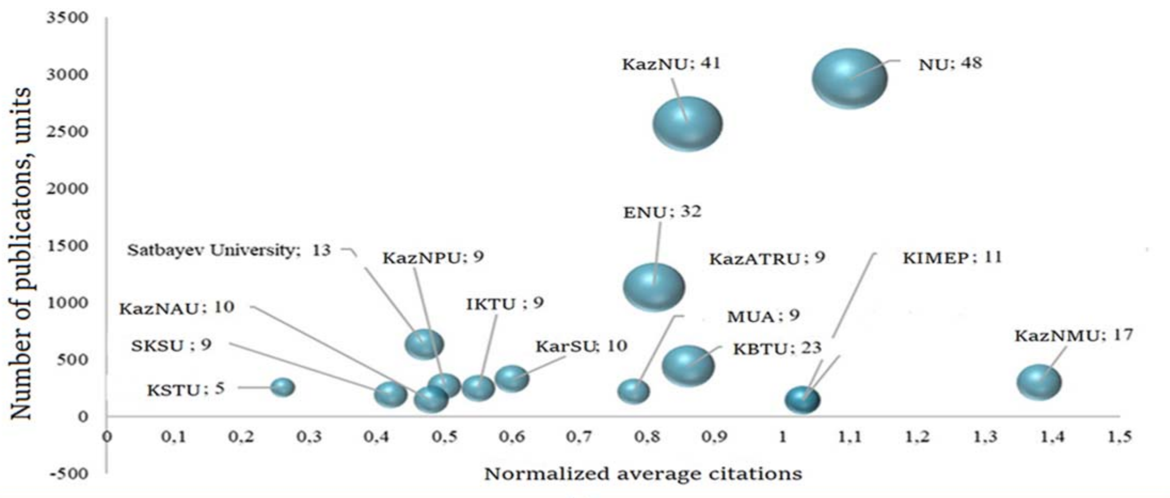
In the group of research organizations, the citation rate of publications is closest to the world average for the Institute of Nuclear Physics (0,90).

The analysis showed that only the articles of the noted universities are on average cited better than the world average.

The Hirsch index (h-index) is a Scientometrics indicator of scientific authority, which gives a comprehensive assessment of both the number of works of the organization and their citation. On the scale of the organizations under consideration, this criterion shows the number of really important publications.

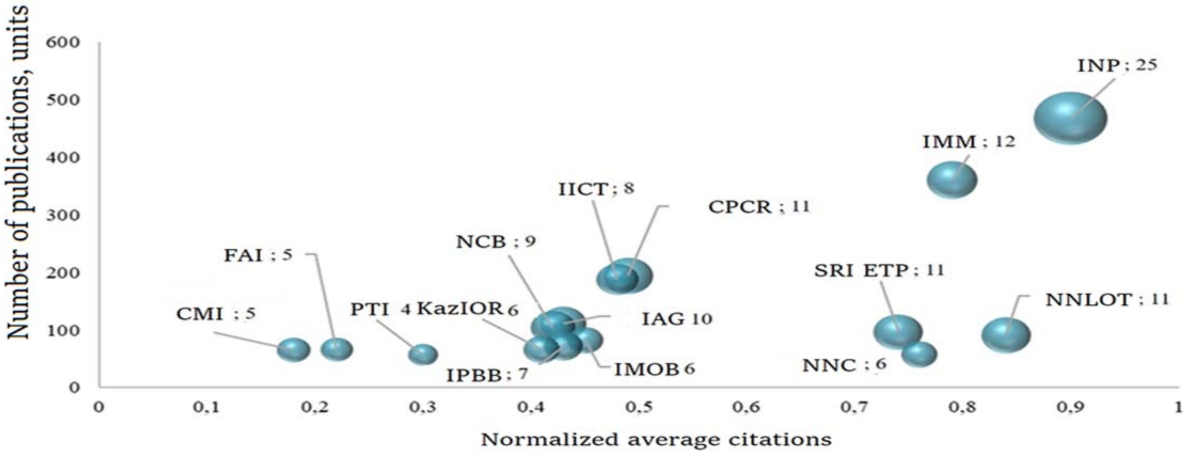
The h-index can be significant only for those organizations where the majority of authors, year after year, conduct research recognized by their peers in the global scientific community, constantly publish their results, and these publications are invariably mentioned in the publications of other scientists [4, 5].

Figures 2.9 and 2.10 show the Hirsch indices of the universities and research institutes selected for the analysis, correlated with Scientometrics indicators - the number of publications of the organization, their normalized average citation. At the same time, the size of the ball reflects the value of the criterion of scientific authority of the organization – h-index.



According to InCites (Clarivate Analytics), as of 23.05.2023.
Figure 2.9. Hirsch index of Kazakhstani universities, top-15

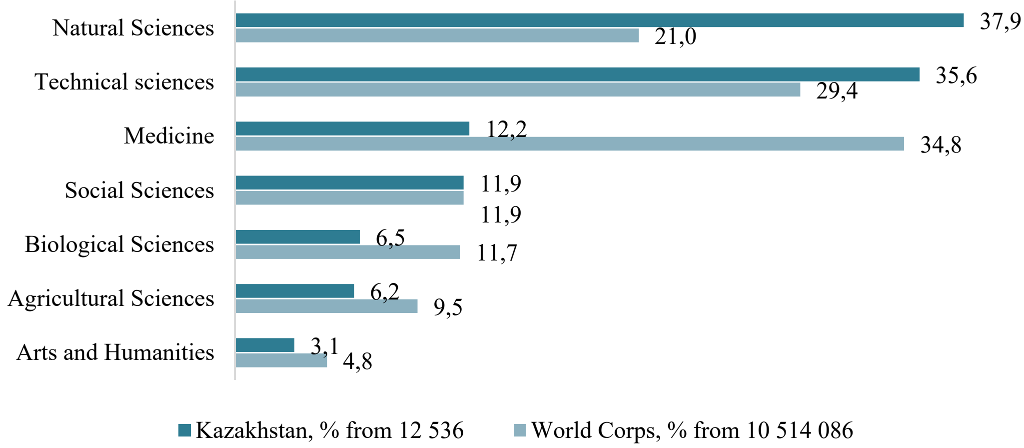
Among higher educational institutions, the absolute leaders in terms of the h-index are Nazarbaev University (48) and Kazakh National University named after Al-Farabi (41). This is followed by the Eurasian National University named after L.N. Gumilev and the Kazakh-British Technical University with the value of this criterion 32 and 23, respectively. At the remaining universities, the h-index index does not exceed 17.



According to InCites (Clarivate Analytics), as of 23.05.2022.
Figure 2.10. Hirsch index of Kazakhstani research institutes, top-15

Among research organizations, the h-index is consistently high at the Institute of Nuclear Physics (25). The Institute of Mathematics and Mathematical Modeling (12), the Research Institute of Experimental and Theoretical Physics (11), the National Nanotechnology Laboratory of Open Type (11), and the Center for Physico-Chemical Methods of Research and Analysis (11) have a value of over 10.

The Web of Science Core Collection database includes international publications covering 147 scientific areas in 7 scientific fields: natural, technical, social, agrarian and biological sciences, medicine, arts and humanities (fig. 2.11).



According to InCites (Clarivate Analytics), as of 23.05.2023
Figure 2.11. Structure of Kazakhstani publications for 2020-2022 by fields of science

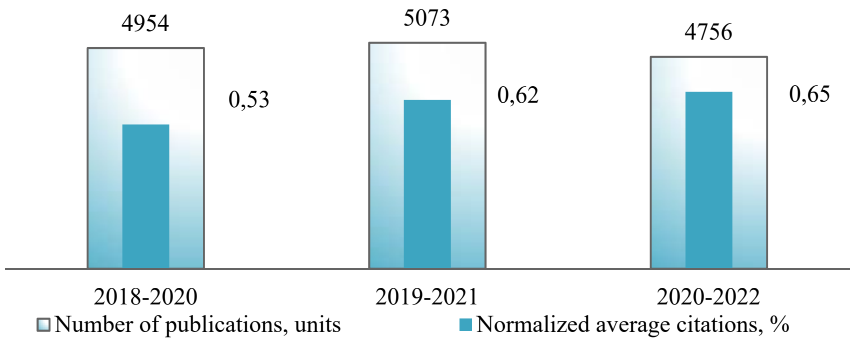
The overwhelming number of Kazakhstani publications in the Web of Science Core Collection traditionally consists of studies on natural and technical sciences. During the period under study, works in the field of natural sciences prevailed, which accounted for 37,9% (4 756 items) of the total number of publications. The share of work in this field is almost twice as high as the world indicator of 21,0% (2 207 688 items). In technical sciences, the results of domestic research are reflected in 35.6% of publications (4 469 items).

At the same time, medicine is represented by almost three times less share of works – 12,2% (1 532 items) than in the world document flow - 34,8% (3 654 197 items).

Only in social sciences the specific weight of Kazakhstan's works is comparable with the world value. In biological and agrarian sciences, as well as in arts and humanities, the share of Kazakhstani publications is 1,5-1,8 times lower than the world values in similar spheres.

To identify the most productive scientific directions based on publication activity and citation rate, all the studied fields of knowledge were analyzed by three time periods.

In the field of natural sciences there was an increase in publication activity in the first two time periods. In 2020-2022, the number of publications amounted to 4756 docs. The value of the citation index does not reach the world average level taken as one. While in 2018-2020 this indicator was 0.65, in the last three-year period it increased only to 0,65 (fig. 2.12).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.12. Dynamics of Kazakhstani publications and their citations in the field of natural sciences

The share of Kazakhstani publications with high citations in the field of natural sciences is small, nevertheless, there is a slight tendency of its increase. Thus, in 2020-2022 it amounted to 0,48%, which is 2 times more compared to previous periods (table 2.13).

Table 2.13. Productivity indicators of Kazakhstani publications in the field of natural sciences

Period	Share of highly cited publications	Share of collaborations	
		international	corporate
2018-2020	0,21	61,59	0,30
2019-2021	0,23	64,48	0,37
2020-2022	0,48	64,07	0,34

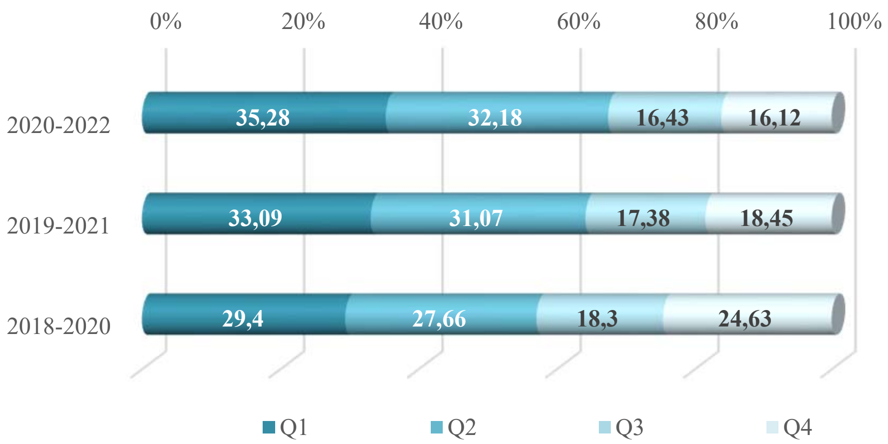
According to InCites (Clarivate Analytics), as of 23.05.2022.

Nowadays, participation in world science is considered not only as a factor of prestige, but also a necessary condition for increasing the productivity of scientific activity. Research performed as part of international collaborations has a higher efficiency. Accordingly, international cooperation is a form of knowledge acquisition that contributes to increasing the productivity of science [5-7].

In Kazakhstani scientific works on natural sciences, the share of international collaborations has a positive dynamics. If in the initial period it amounted to 61,6%, then by 2020-2022 it reached 64.1%.

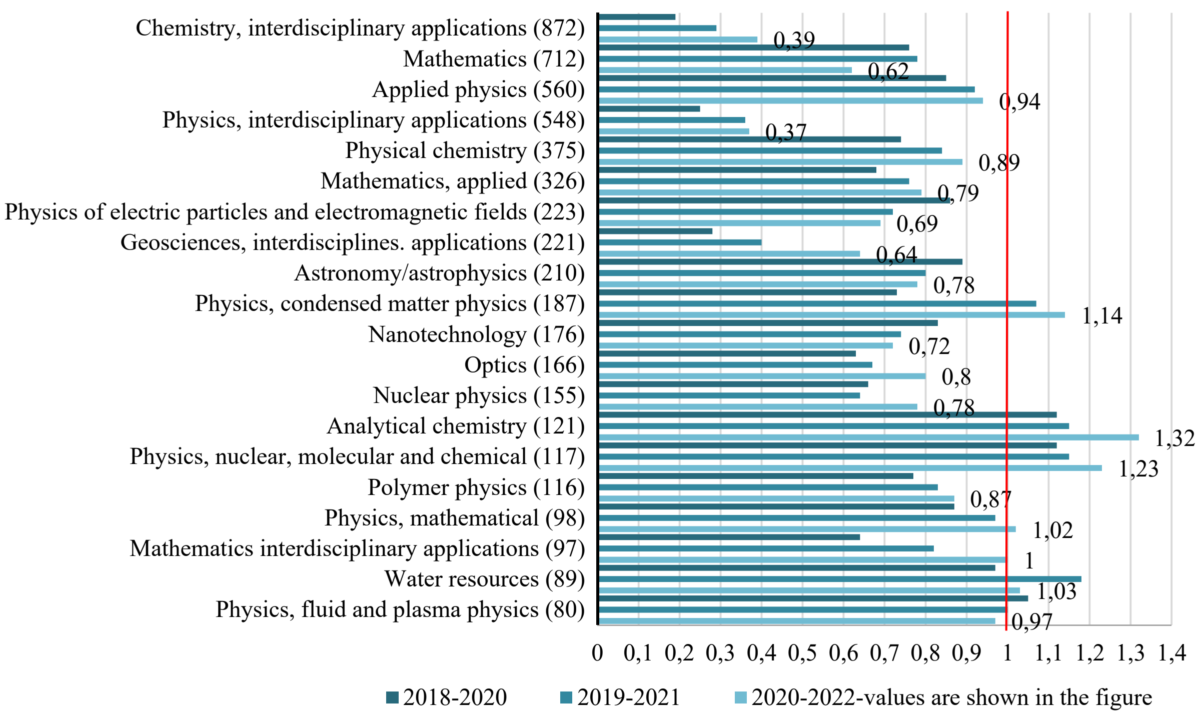
The share of corporate collaborations - associations of scientific organizations with foreign commercial companies in conducting research is relatively low. In the period under study, it amounts to 0,34%.

More than 67% of articles on natural sciences have been published in highly rated journals included in quartiles Q1 and Q2 (fig. 2.13).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.13. Distribution of journals with Kazakhstani publications in the field of natural sciences by quartiles



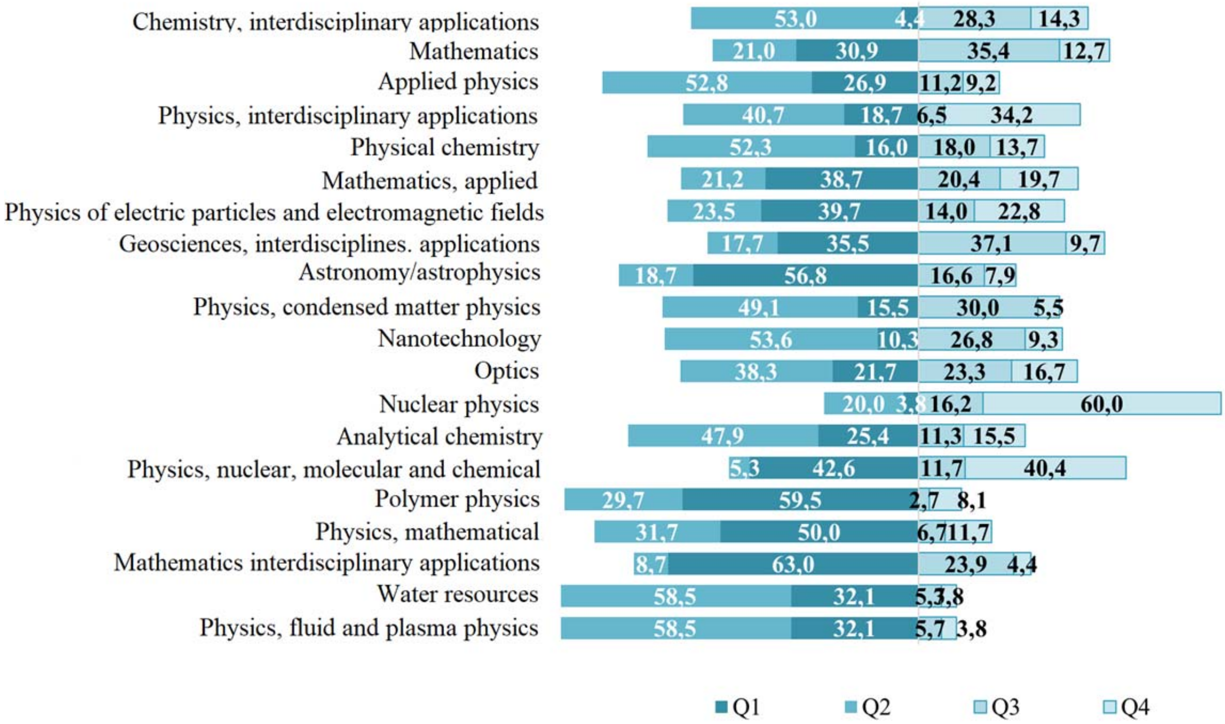
According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.14. Top-20 research areas by number of publications for 2020-2022 in the natural sciences

During the studied periods, research was conducted in the field of natural sciences, which covers 114 specialized areas, including interdisciplinary ones. The top 20 directions for 2020-2022 with the most significant number of publications - from 80 units were analyzed (fig. 2.14).

According to the indicator of scientific performance, such scientific directions as Analytical Chemistry 1,32), Physics, Nuclear, Molecular and Chemical 1,23) and Physics, Condensed Matter Physics 1.14) can be noted. They have reached the world average level of normalized average citation and slightly exceeded it. Mathematics, Interdisciplinary Applications 1.00); Physics, Mathematical 1,02) and Water Resources 1,03).

Quartiles of journals by impact factor are a tool for choosing a publication strategy. The table shows the proportion of articles on the research areas published in journals of various quartiles (table 2.15).



According to InCites (Clarivate Analytics), as of 23.05.2023

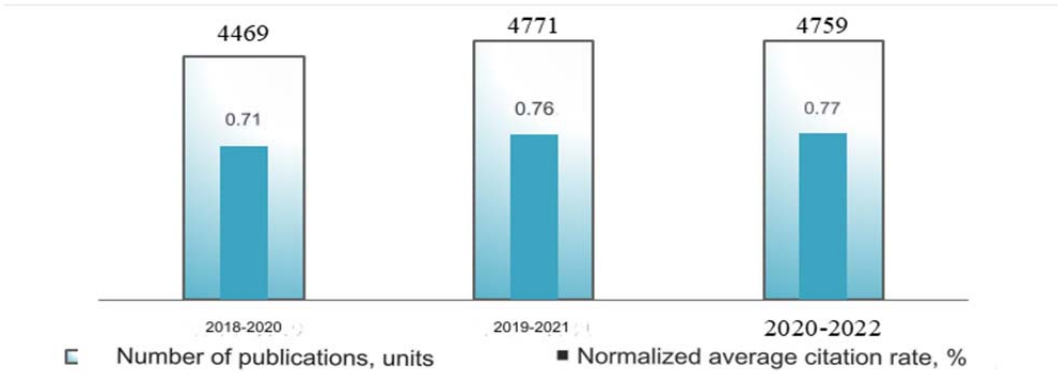
Figure 2.15. Distribution of articles on natural sciences by quartiles of journals in the context of specialized areas

As can be seen from the presented data, almost all scientific fields have published more than half of their works in Q1 and Q2 journals. At the same time, articles in these prestigious publications are presented from 80 to 91% in such areas as Water resources; Physics, liquid and plasma physics; Polymer Physics; Mathematical Physics and Applied Physics. Only works on nuclear Physics (76,2%) are mainly published in journals with quartile Q4 and Q3.

The leading scientific fields in terms of scientific productivity (number of publications), each of which has more than 500 publications, presented their works mainly in journals with quartile Q2: Chemistry, Interdisciplinary Applications

(53%); Mathematics (21%), Applied Physics (53%); Physics, Interdisciplinary Applications (41%).

The field of technical sciences is characterized by an increase in the flow of Kazakhstani publications and their citation. If for 2018-2020, 4469 works were included in the database, the normalized citation of which was 0,71, then for 2020-2022 – 4759 with a performance indicator of 0,77 (fig. 2.16).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.16. Dynamics of Kazakhstani publications and their citation in the field of technical sciences

In comparison with the first period under study in the field of technical sciences, there is an increase in the share of Kazakhstani highly cited works from 0,34% to 0,5% (table 2.14).

Table 2.14. Productivity indicators of Kazakhstani publications for 2020-2022 in the field of technical sciences

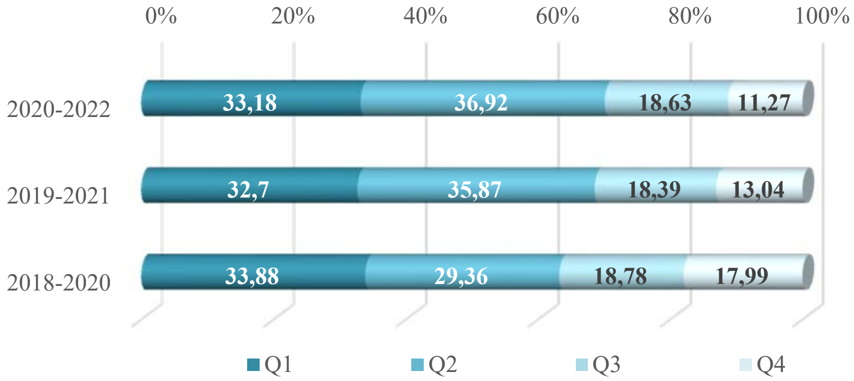
Period	Share of highly cited publications	Share of collaborations	
		international	corporate
2018-2020	0,34	64,11	0,49
2019-2021	0,5	66,34	0,5
2020-2022	0,5	65,16	0,55

According to InCites (Clarivate Analytics), as of 23.05.2023

The level of integration of Kazakhstani scientists into the world scientific community, measured by the number of publications co–authored with foreign researchers, is relatively high - an average of 65,2%. The share of collaborations with commercial organizations involved in conducting research for the analyzed periods is about 0.5%.

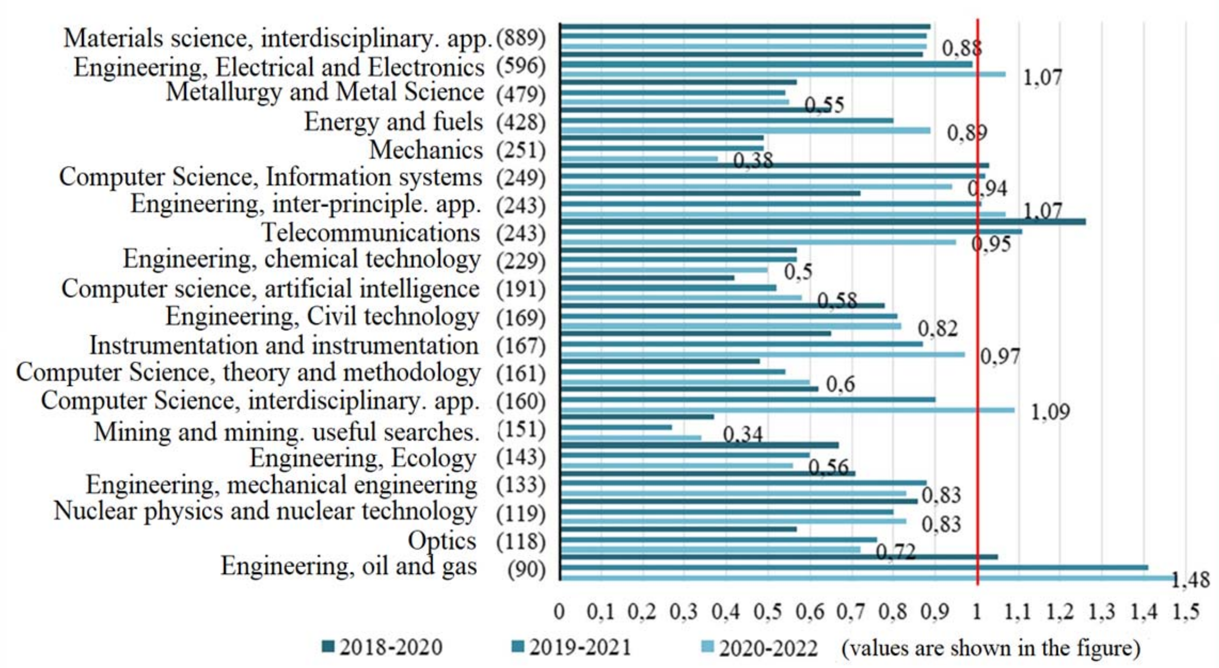
If the percentage of journals of the first and second quartiles in which scientific articles of Kazakhstani researchers are published in the first period is on average 63%, then in the second and third periods it is already about 70% (fig. 2.17).

Kazakhstani works in the field of technical sciences in the Web of Science Core Collection are presented in 180 thematic areas. The Top-20 includes the areas with the most significant number of publications for 2020-2022 (fig. 2.18).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.17. Distribution of journals with Kazakhstani publications in the field of technical sciences by quartiles



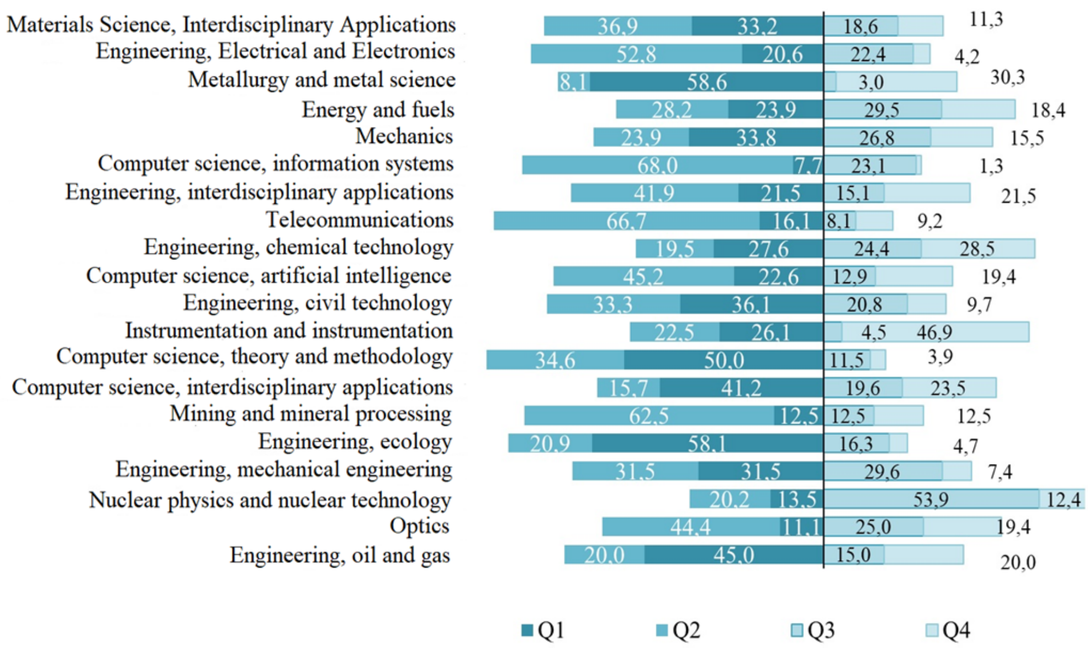
According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.18. Top-20 research directions by the number of publications in the field of technical sciences for 2020-2022

In the three periods studied, the citation of scientific papers in the field of Engineering, oil and gas is consistently higher than the global average, with almost 1,5 times higher in 2020-2022. In the last period, the normalized average citation exceeded one in such thematic areas as Computer Science; Interdisciplinary Applications (1,09); Engineering, Electrical Engineering and Electronics (1,07); Engineering, Interdisciplinary Applications (1,07).

In general, the citation indicator in the field of technical sciences continues to remain low, despite the observed positive dynamics of the publication activity of Kazakhstani researchers.

The distribution of articles of the studied scientific directions in journals of various quartiles is of interest (fig. 2.19).



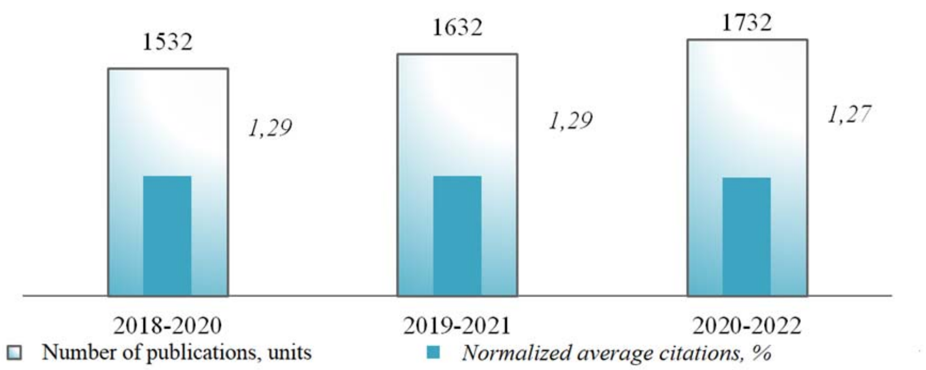
According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.19. Distribution of articles on technical sciences by quartiles of journals in the context of specialized areas

Q1 journals published 50% or more of works in such areas as Metallurgy and Metal Science (58.6%), Engineering, Ecology (58,1%) and Computer Science, Theory and Methodology (50,0%); Q2 journals – Computer Science, Information Systems (68%), Telecommunications (66,7%), Mining business and mineral processing (62,5%) and Engineering, electrical engineering and electronics (52,8%).

In general, in 18 of the 20 analyzed areas in the field of technical sciences, from 52 to 83% of works are presented in prestigious rating journals of quartiles Q1 and Q2.

Publication activity in the field of medicine has a pronounced growth trend. Thus, in 2020-2022, in comparison with 2018-2020, the increase in the number of publications amounted to about 11,5% (fig. 2.20).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.20. Dynamics of Kazakhstani publications and their citation in the field of medicine

The citation index, which characterizes the demand for research results in the field of medicine, is relatively high and exceeds the global average in all the time periods studied. In 2020-2022, it is equal to 1,27.

The level of highly cited articles in the field of medicine is relatively high. However, negative dynamics are also noted for this indicator (table 2.15).

Table 2.15. Indicators of productivity of Kazakhstani publications for 2020-2022 in the field of medicine

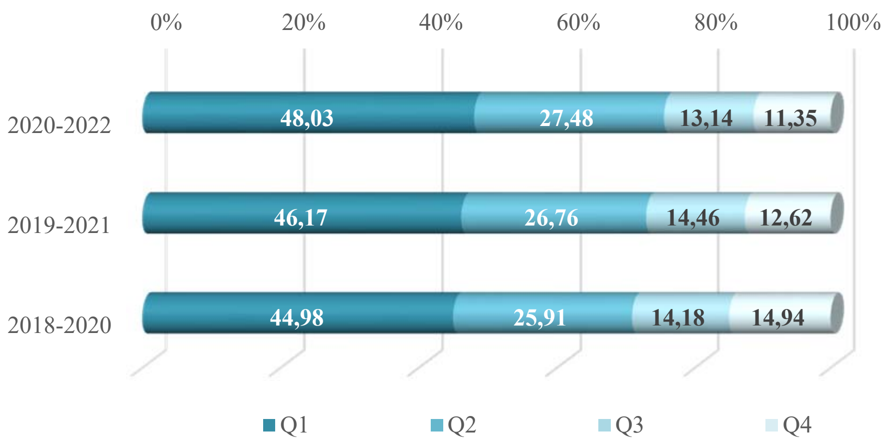
Period	Share of highly cited publications	Share of collaborations	
		international	corporate
2018-2020	2,02	61,49	3,85
2019-2021	1,9	62,99	3,43
2020-2022	1,85	63,91	2,42

According to InCites (Clarivate Analytics), as of 23.05.2023

We can confidently speak about the internationalization of Kazakhstan's medical science and its stable interaction with innovation-oriented businesses.

This is reflected, first of all, in the increase in the share of international publications, the array of which in 2020-2022 reached 63.9% of the total volume of Kazakhstani medical works. For corporate publications that indicate affiliation with one or more commercial companies, it is 2.4%, which is slightly lower than in previous periods.

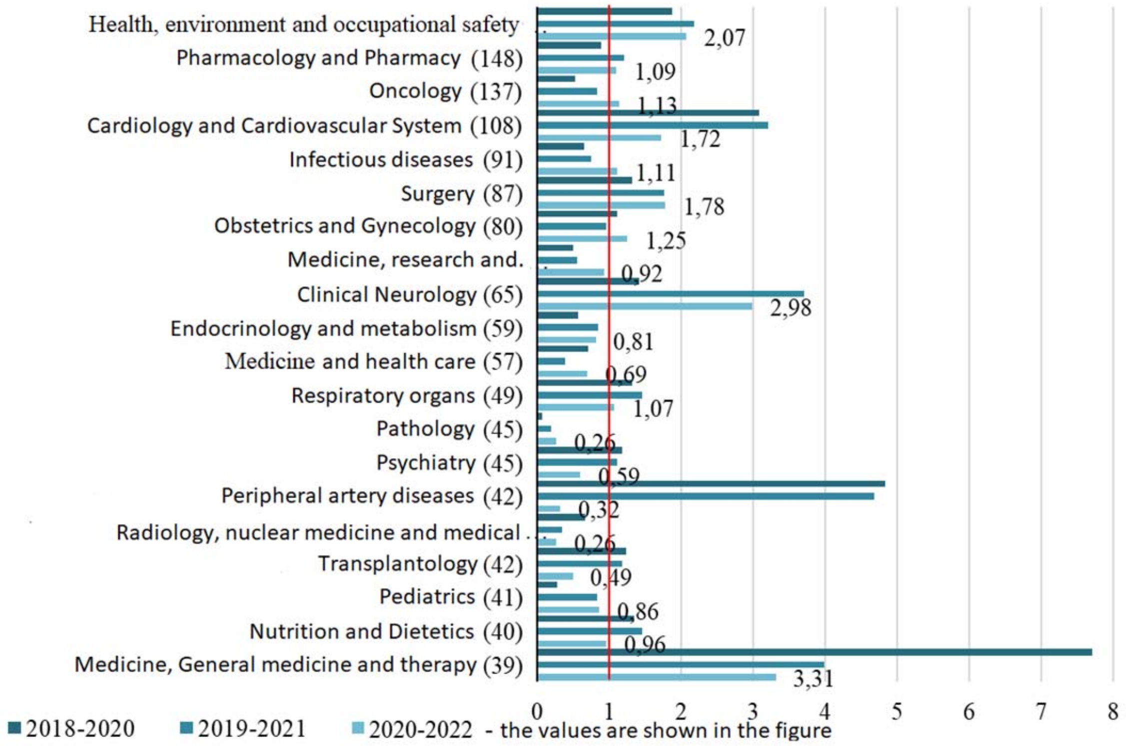
A significant part of the articles – 45-48% – were published in leading scientific journals of the first Q1 quartile, which indirectly indicates the high quality of research by Kazakhstani scientists in the field of medicine. On average, more than 73% of medical works are concentrated in the journals of quartiles Q1 and Q2 (fig. 2.21).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.21. Distribution of journals with Kazakhstani publications in the field of medicine by quartile

For 2020-2022 in the Web of Science Core Collection database scientific works of Kazakhstan in the field of medicine are presented in 123 thematic areas. The significant number of results was published on Health Care, Environmental Protection and Labor Protection (226 docs.); Pharmacology and Pharmacy (148 docs.); Oncology (137 docs.); Cardiology and Cardiovascular System (108 docs.) (fig. 2.22).



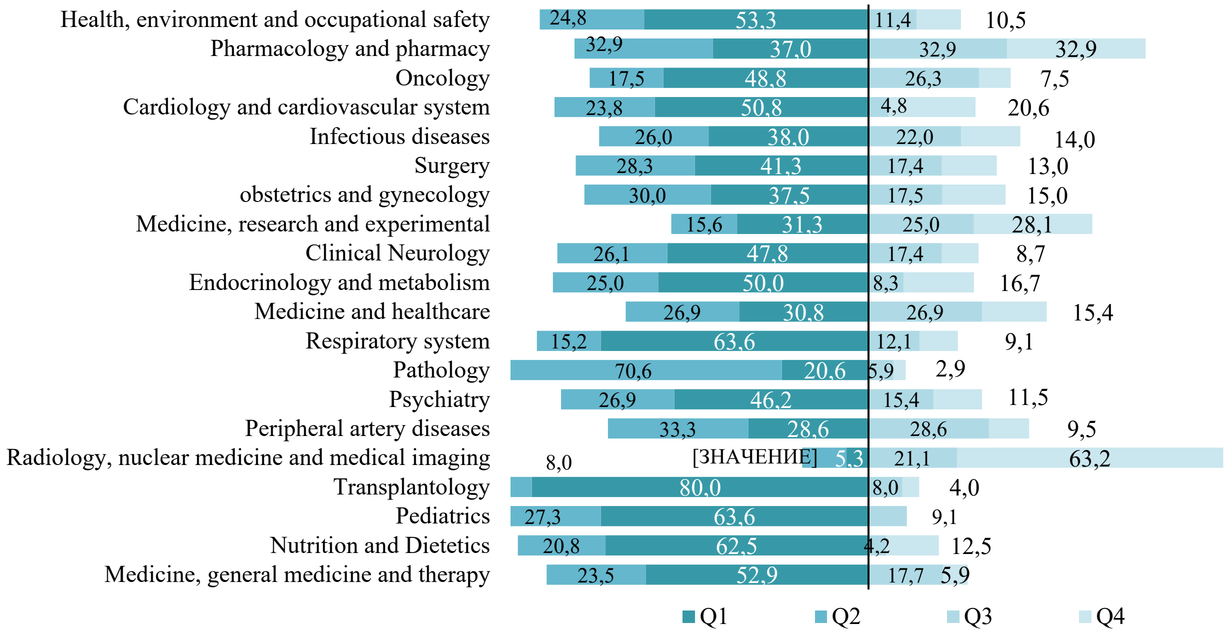
According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.22: Top-20 research areas by number of publications for 2020-2022 in the field of medicine

The normalized average citation of a publication in 6 out of 20 thematic areas exceeds the global average in all periods. At the same time, in Medicine, general medicine and therapy, this indicator in different period have a value from 3,31 to 7,71; in clinical neurology – from 1,47 to 3,7. There was an excess of this indicator by 2 times in Healthcare, Environmental protection and labor protection. Kazakhstan's works on Cardiology and the cardiovascular system with a citation index in three three-year periods of 1,7–3,21 are in stable demand. In general, in 2020-2022, they reached the world average in citations and exceeded its works in 9 scientific areas among those selected for analysis.

Kazakhstani's works on medicine arouse the interest of the world scientific community. In general, in each of the studied periods there are scientific directions, the normalized average citation of which exceeds the world average.

About 50% or more of the articles in half of the 20 research areas in 2020-2022 are presented in Q1 journals. At the same time, the largest share of published works in the publications of this quartile is on Transplantology (80%), Respiratory organs and Pediatrics (63,6%), Nutrition and Dietetics (62,5%) (fig. 2.23).

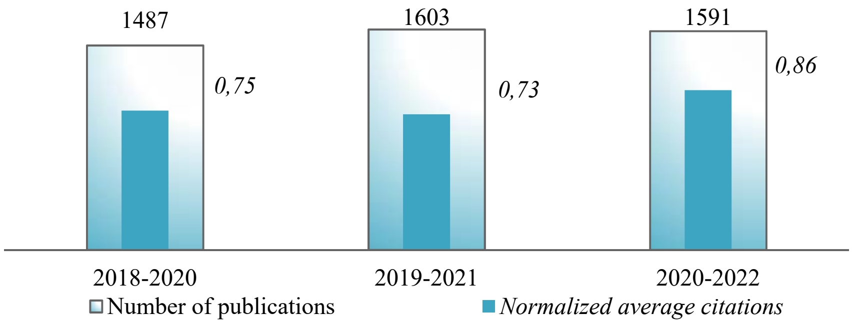


According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.23. Distribution of articles on medical sciences in quartiles of journals in the context of specialized areas

In general, in the field of medical sciences in 19 of the 20 analyzed specialized areas, 56 to 91,2% of works were published in prestigious rating journals of quartiles Q1 and Q2.

In the social sciences, there is a slight positive trend in publication activity. In 2020-2022, compared to the first period, the number of publications increased by 6,5%. The normalized average citation of works is low and does not reach the world average in any of the three periods (fig. 2.24).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.24. Dynamics of Kazakhstani publications and their citation in the field of social sciences

Highly cited publications are present in all the periods under review, their share has increased from 0,07 to 0,25% (Table 2.16).

There is a slight increase in international collaborations in Kazakhstani works in the field of social sciences. If in 2018-2020 their share was 47,2%, in 2020-2022 it amounted to 50,5%.

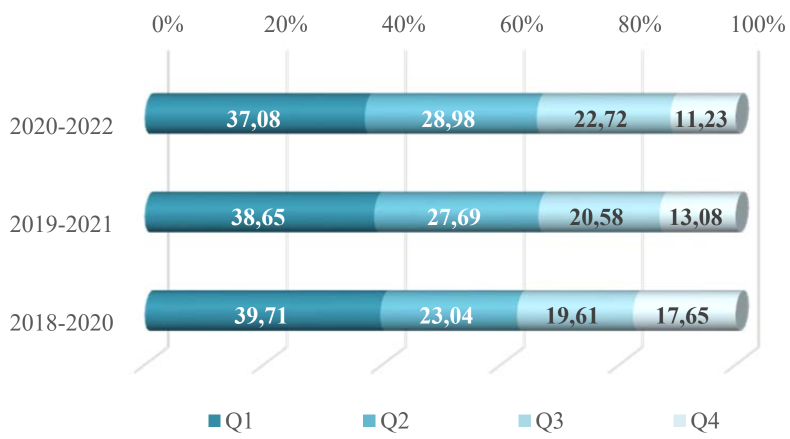
There is a connection with international business, but it is insignificant, in the last period it was equal to 0,5%.

Table 2.16. Indicators of productivity of Kazakhstani publications for 2020-2022 in the field of social sciences

Period	Share of highly cited publications	Share of collaborations	
		international	corporate
2018-2020	0,07	47,21	0,20
2019-2021	0,06	50,09	0,19
2020-2022	0,25	50,47	0,50

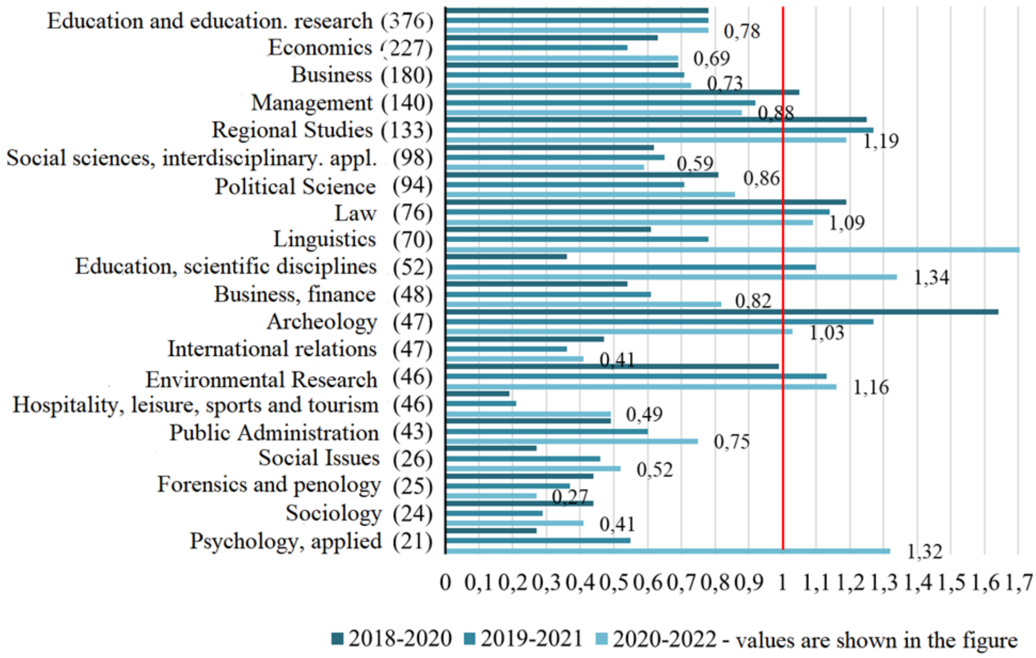
According to InCites (Clarivate Analytics), as of 23.05.2023

Kazakhstani journal articles on social sciences are to a greater extent represented in the publications included in the Q1 quartile – on average, their share for all years is 38,5%. In 2020-2022, more than 66% of Kazakhstani articles were included in the rating journals of quartiles Q1 and Q2 (fig. 2.25).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.25. Distribution of journals with Kazakhstani publications in the field of social sciences by quartile



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.26. Top-20 research areas by number of publications for 2020-2022 in the social sciences

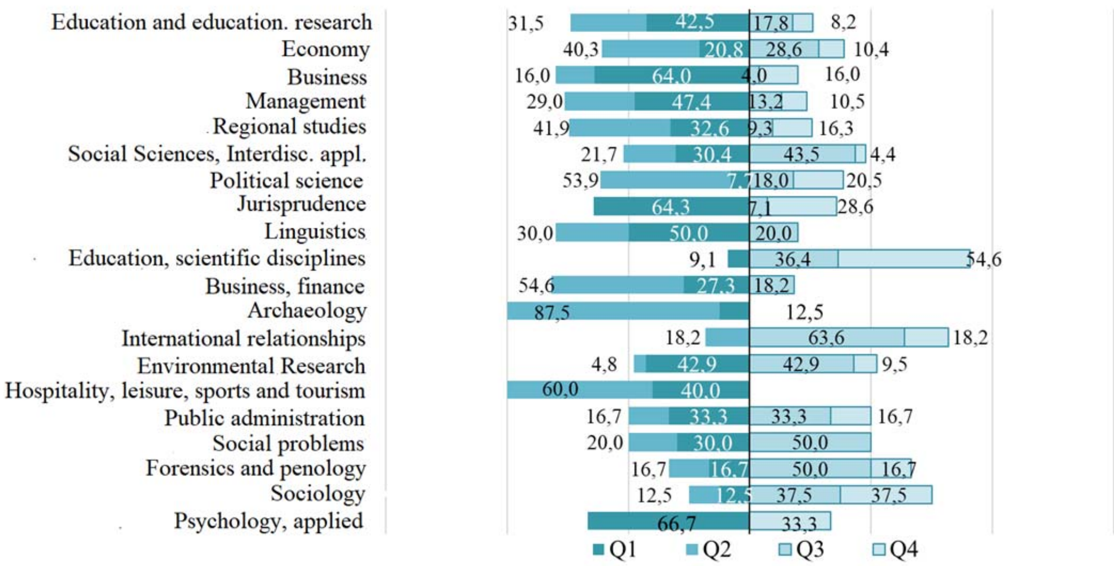
Publications for 2020-2022 in the field of social sciences cover 111 thematic areas. A significant part of the works is presented in 20 of them (fig. 2.26).

Over 100 publications of Kazakhstani scientists are presented in each of the five subject disciplines, such as Education and Educational Research (376 doc.), Economics (235), Business (180), Management (140), Regional Studies (133 doc.).

The stable interest of the world scientific community is aroused by publications on Regional Studies, Archeology, Jurisprudence, Environmental Studies, the citation index of which in all the studied periods exceeds the world average. Articles on Linguistics - 1,85, Education, scientific disciplines - 1,34, applied psychology - 1,32 are well cited.

In general, the citation of the works of Kazakhstani researchers in the field of social sciences does not reach the world average.

A significant share of works in the field of social sciences is presented in Q1 journals only in two subject areas - Applied Psychology (66,7%) and Jurisprudence (66,3%) (fig. 2.27).



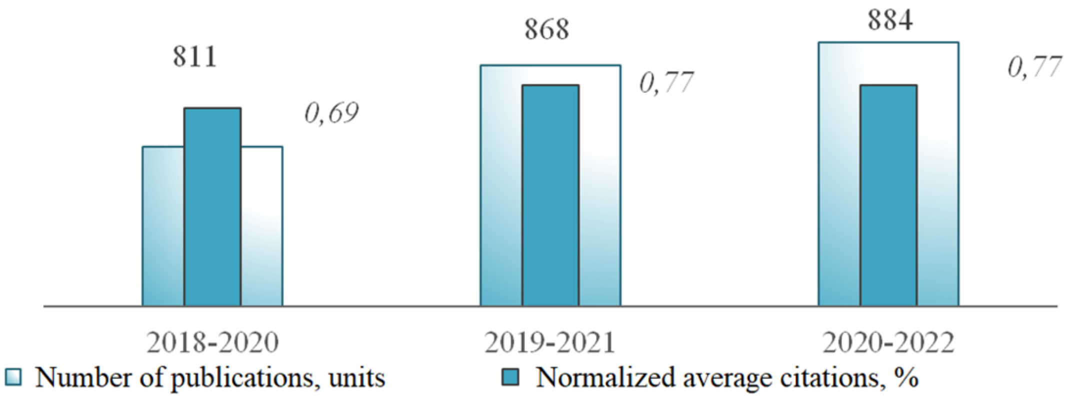
According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.27. Distribution of articles on social sciences in quartiles of journals in the context of specialized areas

To a greater extent, journals with the Q2 quartile publish the results of research in such fields as Archaeology (87,5%), Business, Finance (54,5%) and Political Science (53,8%).

In general, in the field of social sciences in most of the analyzed specialized areas, more than 50% of publications are presented in prestigious journals of quartiles Q1 and Q2, and in such areas as Hospitality, leisure, sports and tourism – 100%.

Biological sciences. The publication activity of Kazakhstani researchers in the field of biological sciences has a positive trend. The number of publications increases in each subsequent period (fig. 2.28).



According to InCites (Clarivate Analytics), as of 23.05.2023
Figure 2.28. Dynamics of Kazakhstani publications and their citations in the field of biological sciences

The citation index does not change over the two three-year time periods. The number of publications in scientific editions refereed by Web of Science Core Collection in 2020-2022 is 884 units, and their normalized average citation rate is 0,77, not reaching the world average value of one.

In the considered field of science, highly cited works are available at all time intervals. In 2020-2022, their share is 0,58% (table 2.17).

Table 2.17. Productivity indicators of Kazakhstani publications for 2020-2022 in biological sciences

Period	Share of highly cited publications	Share of collaborations	
		international	corporate
2018-2020	0,26	63,91	1,18
2019-2021	0,50	67,2	0,75
2020-2022	0,58	70,13	0,58

According to InCites (Clarivate Analytics), as of 23.05.2023

The percentage of works published by Kazakhstani scientists in cooperation with foreign colleagues is quite high, with an average value of about 67%. The connection of researchers with international business is present, but in 2020-2022, compared to the first period, it has weakened by half.

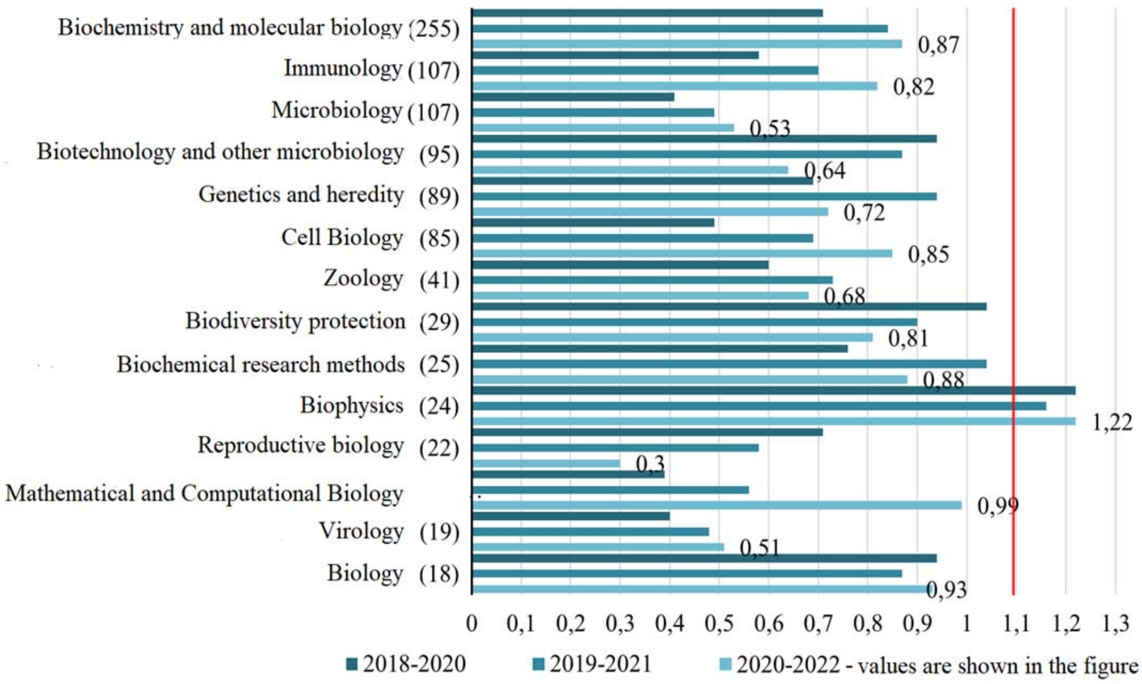
Over 67% of journal articles in the biological sciences are published in the leading publications included in the Q1 and Q2 quartiles (fig. 2.29).

In the Web of Science Core Collection database, Kazakhstani works in the field of biological sciences for 2020-2022 are presented in 100 thematic areas, taking into account interdisciplinary ones (fig. 2.30).

The largest volume of publications for these years falls on such disciplines as Biochemistry and Molecular Biology (255 docs.), Immunology (107), Microbiology (107), Biotechnology and Applied Microbiology (95), Genetics and Heredity (89 docs.), Cell Biology (85 docs.), which is the basis for biomedical and biotechnological developments.

According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.29. Distribution of journals with Kazakhstani publications in biological sciences by quartiles

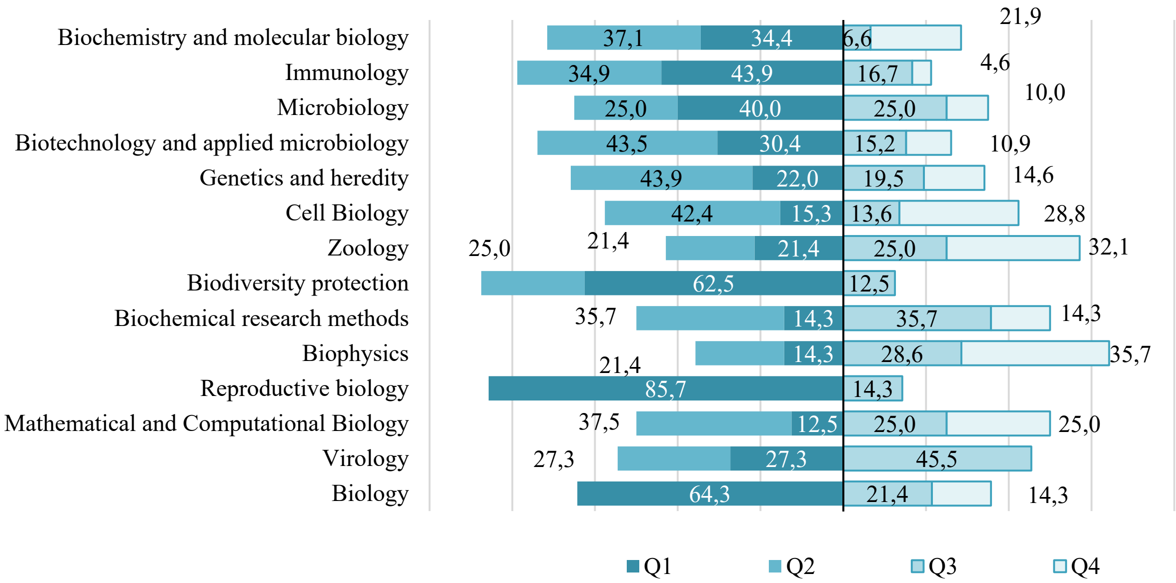


According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.30. Top-14 research areas by number of publications for 2020-2022 in the biological sciences

The level of citation of publications is a sign of the importance of research and an indicator of their impact on the scientific community. In biological sciences, we can distinguish such a thematic area as Biophysics (1,22), which is cited above the world average in all three-year periods. In 2020-2022, works on Mathematical and Computational Biology (0,99) are maximally close to the world average values of the normalized average citation.

Publications of biological profiles in general in the structure of Kazakhstani science are represented twice less than in the world science. Their productivity is low.



According to InCites (Clarivate Analytics), as of 23.05.2023

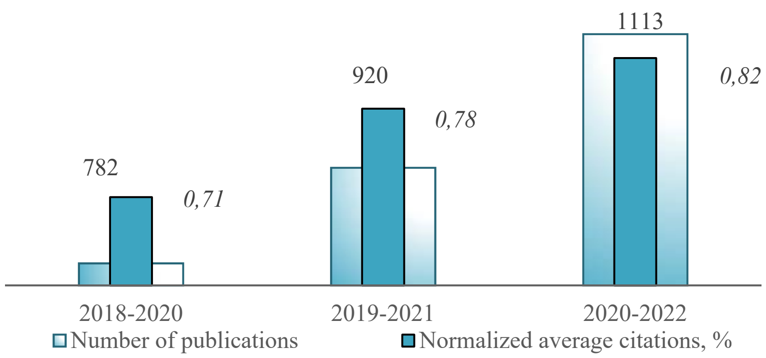
Figure 2.31. Distribution of articles on biological sciences in quartiles of journals in the context of specialized areas

The ideal benchmark for understanding where to publish research results is the quartile of the journal by impact factor in its subject area (fig. 2.31).

The largest share of works in the field of biological sciences is represented in highly rated Q1 journals in such areas as Reproductive Biology (85,7%), Biology (64,3%) and Biodiversity Conservation (62.5%). More than 40% of the articles of the analyzed field are published in Q2 journals in the specialized areas of Genetics and Heredity (43,9%), Biotechnology and Applied Microbiology (43,5%), Cell Biology (42,4%).

In general, in the field of biological sciences in all analyzed specialized areas, except for Biophysics, from 50,0% to 85,5% of works of Kazakhstani researchers are presented in prestigious journals of Q1 and Q2 quartiles.

Agrarian sciences are characterized by a stable growth in the number of publications. Compared to the first period in 2020-2022, the publication activity of domestic researchers increased by 31% (fig. 2.32).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.32. Dynamics of Kazakhstani publications and their citations in the field of agrarian sciences

Interest in the works of Kazakhstani scientists is growing, which can be judged by the increase in the normalized average citation rate in each subsequent time interval, but the value of this indicator does not yet reach one. This means that Kazakhstani articles are cited less than world articles in this field.

Highly cited works covering the research on agricultural sciences are available in each time interval. If in the first two periods their share of the total volume of publications was 0,26% and 0,54%, respectively, in the last period - already 0,72% (table 2.18).

Table 2.18. Productivity indicators of publications of Kazakhstan in the field of agricultural sciences

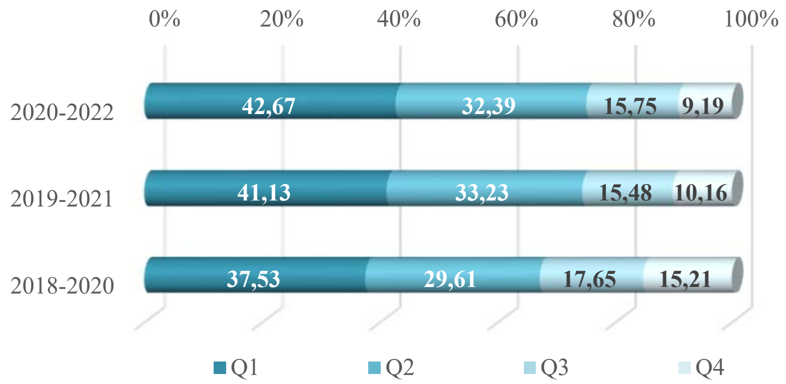
Period	Share of highly cited publications	Share of collaborations	
		international	corporate
2018-2020	0,26	69,69	0,13
2019-2021	0,54	72,07	0,33
2020-2022	0,72	70,62	0,63

According to InCites (Clarivate Analytics), as of 23.05.2023

Jointly with researchers from other countries 70,6% of published works were prepared.

There are insignificant connections with commercial enterprises, which vary in the first two periods from 0,13 to 0,33%. In 2020-2022, this indicator increased markedly to 0,63%.

The positive dynamics of Kazakhstani publications presented in the journals of agrarian profile with the quartile Q1 is evident, with a simultaneous decrease in publications with the quartile Q4 (fig. 2.33).

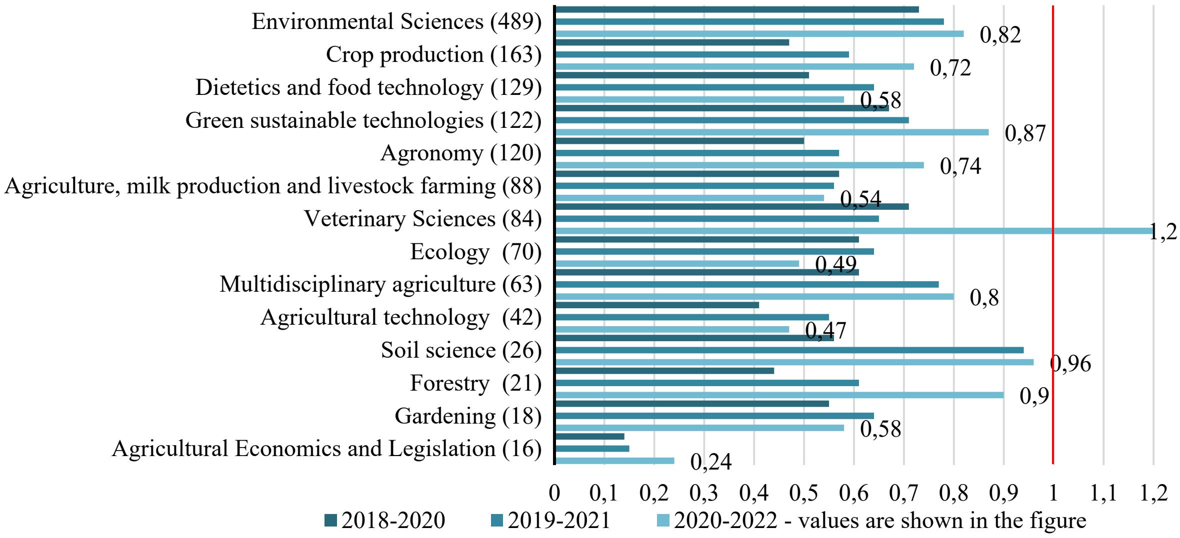


According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.33. Distribution of journals with Kazakhstani publications in the field of agricultural sciences by quartiles

In each subsequent period, the total share in journals Q1 and Q2 increased and in 2020-2022 amounted to 75,1%, which can be regarded as a positive fact that indirectly influenced the growth of the normalized average citation rate of publications.

During the periods under study, the works in the field of agricultural sciences were conducted in more than 82 thematic areas, including interdisciplinary ones. The top 14 directions with the most significant number of publications for 2020-2022 were analyzed (fig. 2.34).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.34. Top-14 research areas by number of publications for 2020-2022 in agricultural sciences

The number of publications in each agricultural science area is low, with only four science areas having more than 100 publications over the three years period. These include Environmental Sciences (489 units), Plant Production (163), Dietetics and Food Technology (129 units), and Green Sustainable Technologies (122 units).

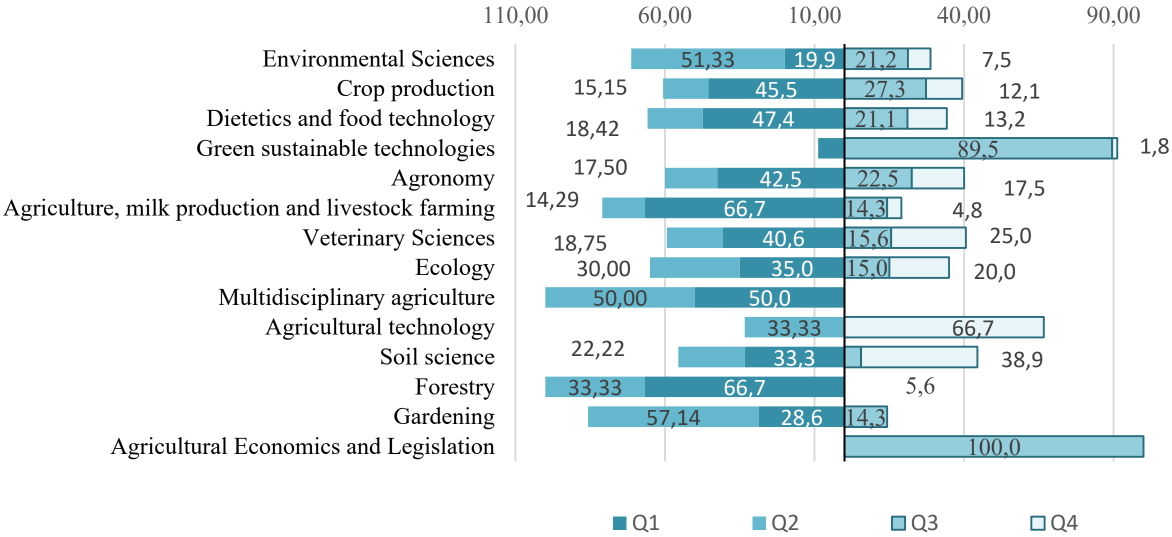
According to the normalized average citation rate, only in the last period of 2020-2022 we can highlight one thematic area - Veterinary Sciences (1,2), whose publications reached and slightly exceeded the world average.

Regarding scientific performance, we can also mention Soil Science, in which this indicator is dynamically improving. In the last period, with a value of 0,96, it came close to the world average indicator equal to one. The other directions under consideration do not reach the world level regarding citation. In general, the productivity of the entire array of publications on agricultural issues is insignificant.

The largest share of works in the field of agricultural sciences is presented in highly rated Q1 journals in such directions as Agriculture, Milk Production and Animal Husbandry (66,7%), as well as Forestry (66,7%) (fig. 2.35).

More than 50% of the articles of the analyzed area were published in Q2 journals in the specialized directions of Horticulture (57,1%), Environmental Sciences (51,3%).

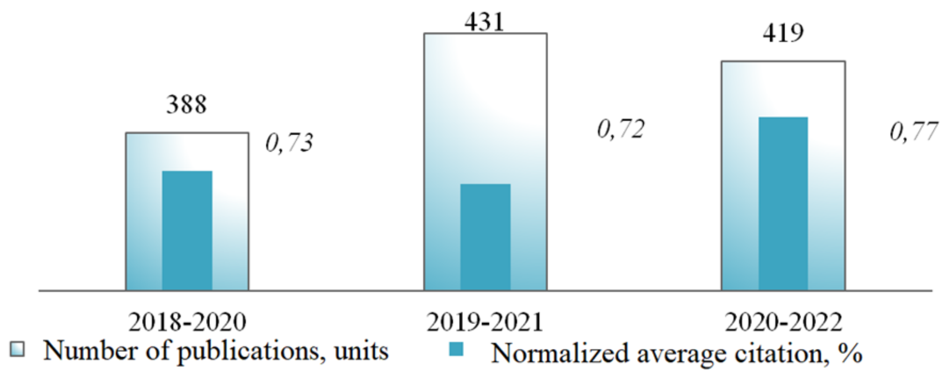
It is impossible not to mention two specialized areas, the total share of articles which in Q1 and Q2 journals was 100% - these are multidisciplinary Agriculture and Forestry.



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.35. Distribution of articles on agricultural sciences in quartiles of journals in the context of specialized areas

In the field of arts and humanities the dynamics of publication activity is unstable. In 2020-2022, the number of publications increased by 7,4% compared to the first period, but decreased by almost 3,0% compared to the second period. The citation rate of publications in this sphere does not reach the world average level (fig. 2.36).



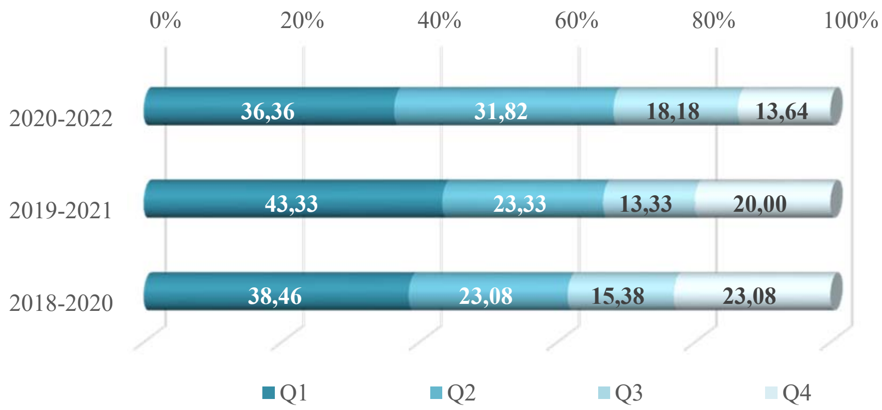
According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.36. Dynamics of Kazakhstani publications and their citation rate in the field of arts and humanities

In the studied area of knowledge from the productivity indicators there are only international collaborations, but their share is insignificant, on average for the studied periods is about 22%.

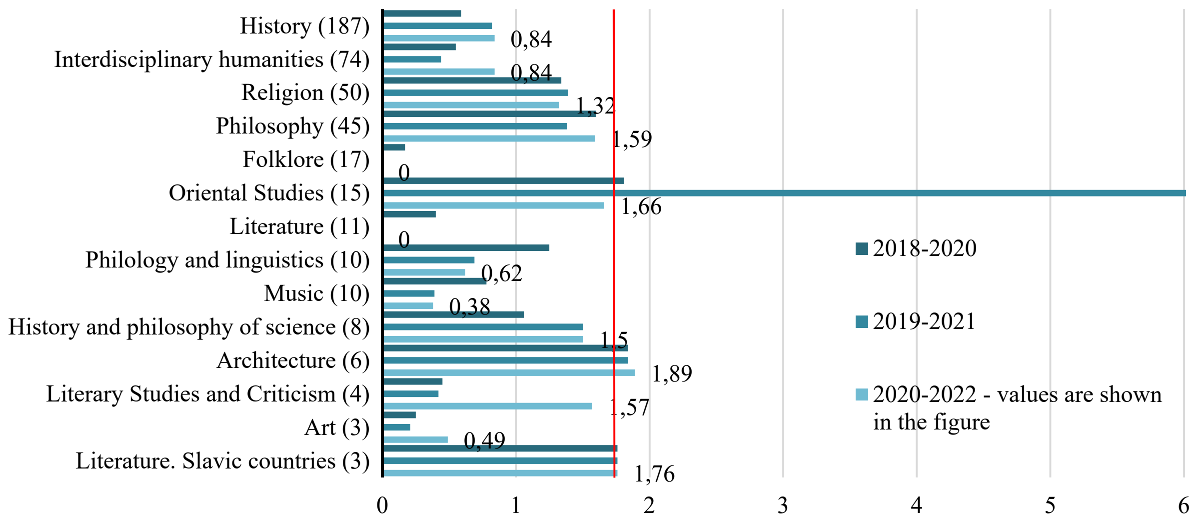
At the same time, a certain increase in each subsequent time interval of the total share of journal articles published in the ranking publications with quartiles Q1 and Q2 is positive, which in 2020-2022 compared to the initial period increased by 6,7% and amounted to 68,2% (fig. 2.37).

In 2020-2022, arts and humanities research covered 55 thematic areas. The top 14 directions for these years with the number of publications from 3 and above were analyzed (fig. 2.38).



According to InCites (Clarivate Analytics), as of 23.05.2023

Figure 2.37. Distribution of journals with Kazakhstani publications in arts and humanities by quartiles



According to InCites (Clarivate Analytics), as of 23.05.2023

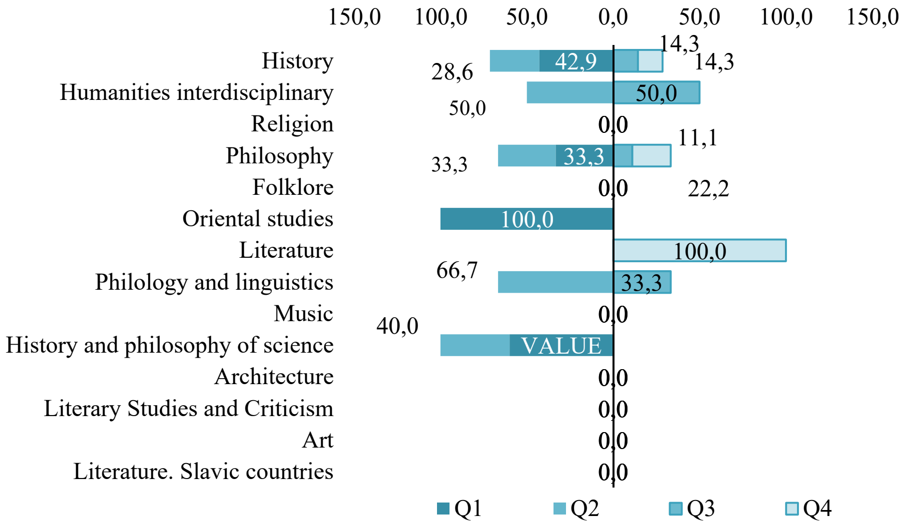
Figure 2.38. Top-14 research areas by number of publications for 2020-2022 in the arts and humanities

The most productive directions according to this indicator are History (187 units) and Humanities (74 units). Religion and Philosophy can be noted, for which the research results are reflected in 50 and 45 publications, respectively.

In terms of the citation rate of publications, 6 out of 14 specialized areas under consideration consistently exceed the world average in all time periods. These include such directions as Architecture (1,89), Literature, Slavic countries (1,78), Oriental studies (1,66), Philosophy (1,59), History and philosophy of science (1,50), Religion (1,32). Kazakhstani's works on Literary Studies and Criticism are of high interest to scholars (1,57).

In general, in the field of arts and humanities, despite the presence of a fairly high normalized average citation rate in some thematic areas, the publication productivity indicators are not high.

Of the 14 specialized areas selected for analysis, only half (50%) have articles in ranked journals with an impact factor (fig. 2.39).



According to InCites (Clarivate Analytics), as of 23.05.2023

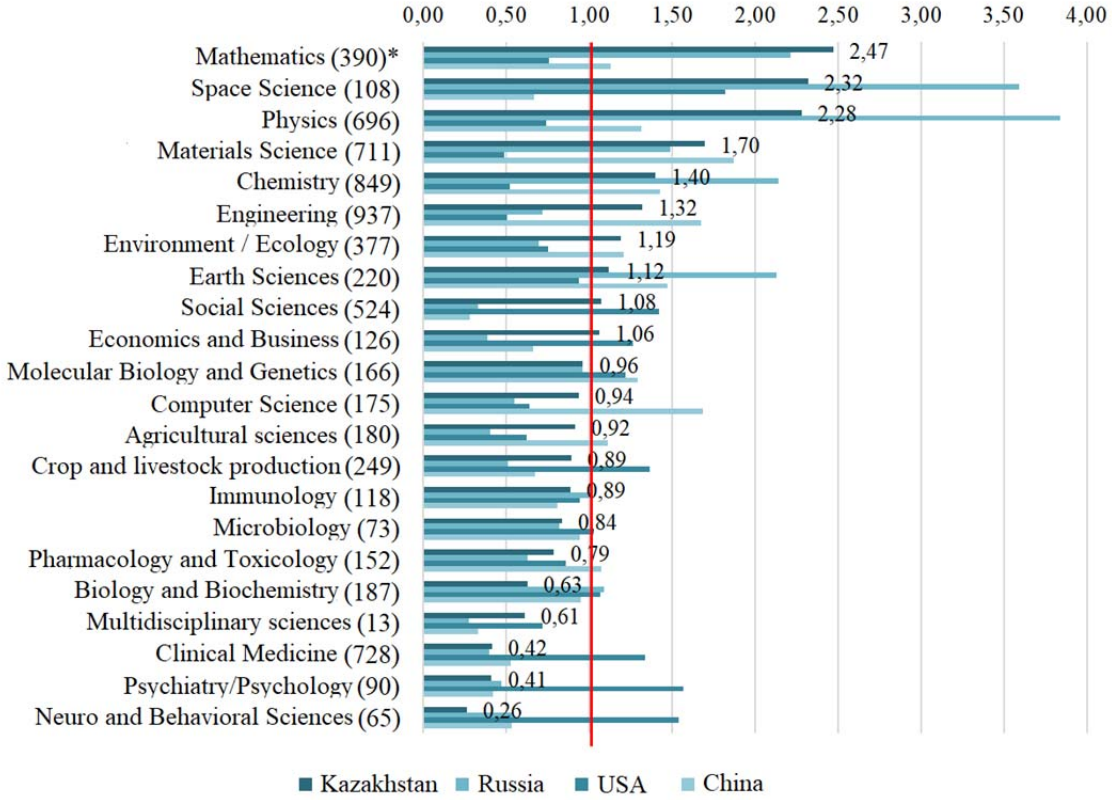
Figure 2.39. Distribution of articles on art and humanities in quartiles of journals in the context of specialized areas

The largest share of works in Q1 journals in such directions as Oriental Studies (100%), History and Philosophy of Science (60%), History (42,9%); in Q2 journals - Philology and Linguistics (66,7%) and Humanities Interdisciplinary (50%).

One of the indicators to assess the scientific orientation of a country is **the index of scientific specialization,** defined as the ratio of the share of subject areas in the total volume of publications of the country to the same indicator in the global document flow. If this index for works in any scientific discipline is greater than one, it means that this discipline belongs to the sphere of scientific specialization of the country [8].

During the study period, the areas of specialization of domestic science are Mathematics, Space and Earth Sciences, Physics, Materials Science, Chemistry, Engineering, Environment/Ecology and recently - Social Sciences, Economics and Business. In general, these 10 areas of science account for about 70% of the publications of Kazakhstani scientists in the database. The index of scientific specialization varies in the range of 0,26-2,47. Insufficiently developed in Kazakhstan, by world standards, remain research in the field of Life Sciences: medicine, biological areas. Neuro-behavioral sciences, Psychiatry/psychology and Clinical medicine have very low values of the index of scientific specialization - 0,26-0,42 (fig. 2.40).

Russia's scientific orientation shows a similar situation: high levels of specialization belong to Physics, Space and Earth Sciences, Mathematics, Chemistry and Materials Science. In contrast to Kazakhstan, the areas of scientific specialization also include Biology and Biochemistry, Plant and Livestock Breeding.



* The number of publications of the Republic of Kazakhstan is given in brackets

Values of the index of scientific specialization are presented for Kazakhstan only

Figure 2.40. Scientific specialization of Kazakhstan in comparison with Russia, USA and China

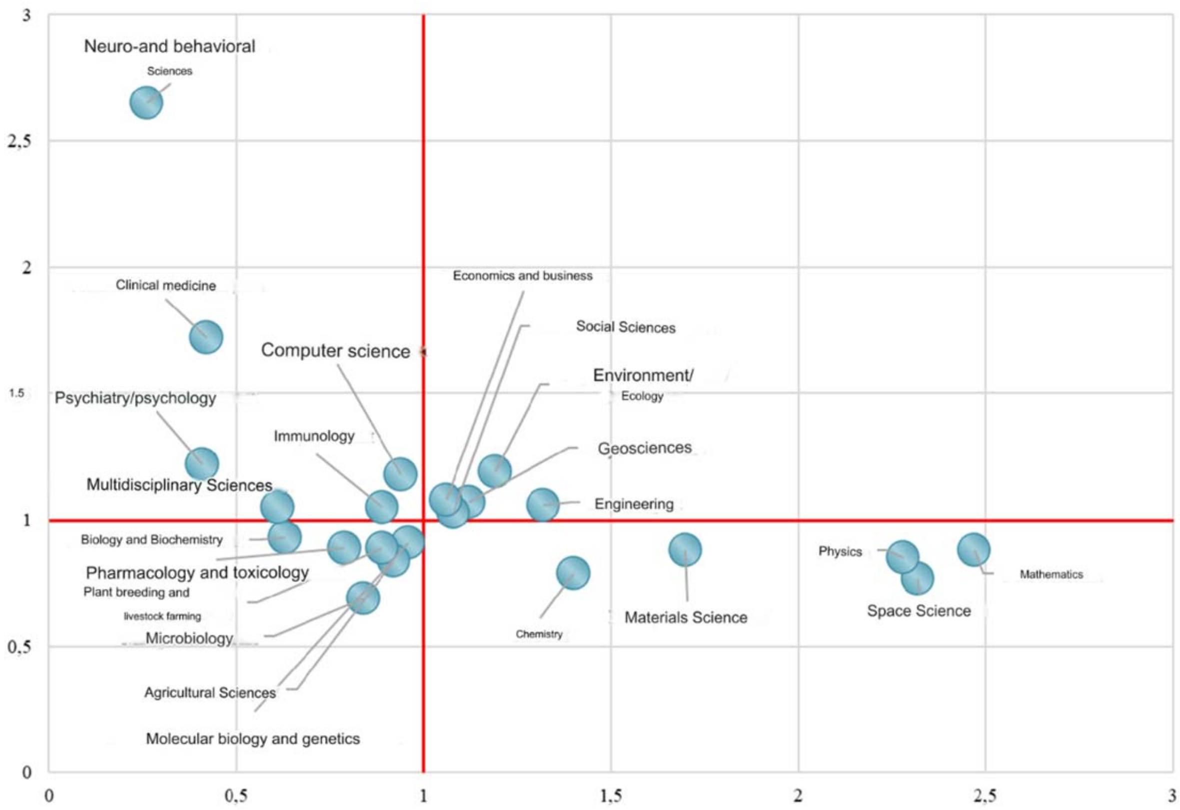
In comparison, in the United States, more emphasis is placed on Space Science, Medical, Biological and Social Sciences (Psychiatry/Psychology, Neuro and Behavioral Sciences, Social Sciences, Immunology, Clinical Medicine, Economics and Business, Molecular Biology and Genetics, Biology and Biochemistry, Microbiology).

The peculiarity of Chinese science is the development of such areas as Materials Science, Computer Science, Engineering, Agricultural Science, Pharmacology and Toxicology. Space science, which is one of the highest priority subject areas of the above three countries, is on the 16th position in the ranking of China's scientific specialization.

Using bibliometric indicators relative to the world average values SWOT-analysis of the state of development of scientific research areas of Kazakhstani science was carried out [9].

The results of SWOT-analysis allow us to identify the strengths and weaknesses of domestic science, potential opportunities and threats. The index of scientific specialization and the normalized average citation rate of publications for 2020-2022 were used as criteria for the analysis (fig. 2.41).

According to SWOT-analysis, subject areas that have values of the index of scientific specialization and normalized average citation above the world average level equal to one, belong to the strengths of the country's science **(Strengths).**



According to InCites (Clarivate Analytics), as of 25.05.2023
Figure 2.41. SWOT analysis of subject areas of science in Kazakhstan, 2020-2022.

These include:

Environment / Ecology, where there is an excess of 19% above the world average for both indicators. This area has already been a scientific specialization of the country since 2016-2018, and the demand for its results is above average in the last two periods;

Economics and Business represents the scientific specialization of the country from 2019-2021, and in terms of citations exceeded the world average by 8% in the last period;

Earth Sciences is steadily among the scientific specialization of the country, and in the last period has also reached the citation level with an excess of 7%.

Engineering represents the scientific specialization of the country throughout all time periods, with a publication rate of 32% above 1 for 2020-2022. At the same time, the citation rate in the last 2 periods also exceeds the world average level by 4-6%;

Social sciences have unstable dynamics for both criteria under study. However, their values in recent years have increased by 8 and 3% relative to the world level.

In these subject areas, related to the scientific specialization of domestic science, research is conducted, the results of which make a significant contribution to Kazakhstan and world science and are in demand by the world scientific community.

Weaknesses of Kazakhstani science are the subject areas with high publication activity (1,40 - 2,47) and low citation rate (0,77-0,88), i.e. areas representing scientific specialization of the country, but with insufficient demand for research results. For 2020-2022 they are also represented by 5 areas:

Mathematics has the highest index of scientific specialization in the country, exceeding the world average level by almost 2.5 times, in previous periods - even more than 3.6 times. This field has always been one of the strengths of domestic science, showing a high level of citation, the value of which, unfortunately, fell in 2020-2022 to 0,88. This science, in order to return to the category of strong, needs to increase the level of research performed by only 0,12%;

Space science has a similar picture by the criterion «index of scientific specialization», which characterizes publication activity. In dynamics, this area has been classified as a strong area of science for two consecutive periods, but since 2019 there is a decrease in the citation index by 23-24% from the global average;

Physics as a field of scientific specialization of Kazakhstan has a high index (2,72 - 2,28) throughout the time, while the citation index remains below the world average level by 15-23%;

Materials science consistently exceeds the world average in terms of publication activity and in the previous period was even in the strong category. In order to return there, it is necessary to increase the normalized average citation rate by 12% by improving the quality of publications.

Chemistry, like all the above subject areas, has consistently represented the scientific specialization of the country throughout time. There is a positive trend in the citation rate, but to reach the world average level it is necessary to increase the demand for publications by 21%.

In order to strengthen the position of the areas representing the weak side of science, it is necessary to evaluate internal factors that would contribute to improving the quality of research and publications, respectively, to increase their relevance. In this case, the first three areas can reduce the number of studies and publications in favor of improving their quality.

One of the significant aspects of the development of Kazakhstani science are **Opportunities.** These are areas that have low values of the index of scientific specialization (0,26 - 0,94), and high - normalized average citation (1,05 - 2,65). They include:

Neuro-behavioral sciences with the lowest index of scientific specialization have the highest citation rate. Here we observe a negative dynamics of publication activity and a significant increase in the normalized average citation rate starting from 2017-2019. To improve the situation in this area, it is necessary to maintain the quality of publications and strengthen their growth rate compared to the global average by almost four times;

Clinical medicine is characterized by consistently low values for the first criterion - 0,40 - 0,44 and exceeding the world average for the second criterion (1,72 - 3,05). In this subject area it is necessary to strengthen publication activity while maintaining the same quality. The growth rate of publications of

Kazakhstani scientists should be at least 2.5 times ahead of the growth rate of publications on Clinical Medicine in the world;

Computer science and Immunology were the specialization of the country in some periods under study and have the highest values in this group according to the specialization index. The citation rate is slightly higher than the world average. With a slight increase in the share of publications and maintaining their quality, these subject areas can increase the number of strong categories of Kazakhstani science;

Psychiatry/psychology, as well as Clinical Medicine, does not reach the index of scientific specialization for 2020-2022 to 1 almost 60%, although in the initial periods it had rather high values - 0,85 - 0,90. It needs to recover and even increase the productivity of research without losing its high quality (1,14 - 1,34);

Multidisciplinary sciences have increased the growth rate of publications only in recent years. To reach the world level at this stage, it is necessary to increase publication activity by at least 40%.

These fields can be categorized as promising. Low shares of publications, probably, indicate that the development of disciplines in these areas in Kazakhstan is not given enough attention. With an increase in publication activity and maintaining the same quality of research, they have the potential to move in the future into the category of strengths of Kazakhstani science. At the moment, to move to the category of «strong» it is necessary to slightly increase the growth rate of publications in such subject areas as computer science and immunology.

The areas that do not reach the world level both in terms of publication activity and citations pose a threat (Threats) to domestic science. This group includes biomedical sciences and agro-industrial complex:

Biology and Biochemistry, Pharmacology and Toxicology, representing the country's specialization in 2015-2017, further show a trend of decreasing productivity to 0,63 and 0,79 and increasing normalized average citation to 0,93 and 0,89 units in 2020-2022. To achieve the world average level, these directions need to increase the share of publications of Kazakhstani scientists more than 1,6 times, and their quality - 1.1 and more times;

In the direction of *Molecular Biology and Genetics* there is a tendency of growth of the index of scientific specialization. According to the citation index, this direction exceeded the world average level in some periods. It is obvious that there is enough potential here and with the increase in the share of publications of Kazakhstani scientists by 4% and citation rate by 9% by improving their quality it is possible to move it to the category of strong.

In recent years *Microbiology* by both criteria does not reach the world average level. However, in some previous periods it belonged to the specialization of the country and constituted the strength and potential of domestic science. This science needs to raise productivity to the level of 2016-2018 and 2017-2019 and the quality of work to the level of 2017-2019 and 2019-2021;

Positive dynamics of the share of publications is noted in the fields of agro-industrial complex: *Agrarian sciences, Plant growing and animal husbandry*.

These sciences to achieve the world average level should increase the share of publications of Kazakhstani scientists by 8 and 11% and improve the quality of research by 16 and 11%, respectively.

The areas presented as a threat, in order to reach the world average level, need measures to strengthen these sciences and improve the quality of research by moving from breeding research to the gene level and biotechnological approaches.

In general, for 2020-2022, half of the subject areas of Kazakhstani science are presented as strong or having the opportunity to move into the category of strong. Such subject areas as Economics and Business, Earth Sciences, Social Sciences have improved their indicators in comparison with the previous period.

SWOT-analysis, providing a structured description of the state of the subject areas of science in comparison with the world average indicators, is effective for determining directions and setting priorities in the formation of strategic alternatives and justification of decisions.

Thus, it should be assumed that the main external factors constraining the development of science in Kazakhstan may be the lack of clear national priorities, the decline in the prestige of scientists, general bureaucratization, as well as the lack of specialized personnel and the outflow of scientists abroad.

2.3. Patent activity

Patent activity is an indicator illustrating the activity of patenting activity of the country in terms of registered patents and patent applications of the subjects of the country, as well as foreign residents.

Patent registration in the Republic of Kazakhstan is carried out in accordance with the requirements of the Patent Law № 427 dated 16.07.1999, based on the Rules of registration of industrial property objects in the State Register of Inventions, State Register of Utility Models, State Register of Industrial Designs and issuance of protection documents and their duplicates, invalidation and early termination of patents, approved by the Order of the Minister of Justice of the Republic of Kazakhstan dated 29.08.2018. № 1341 by the Republican State Enterprise on the right of economic management «National Institute of Intellectual Property» of the Ministry of Justice of the Republic of Kazakhstan (hereinafter - NIIP).

The analysis of patent activity is based on the official information of NIIP.

The main attention is paid to the data on filed applications, which are most often used for quantitative assessment of activity in the field of intellectual property.

According to NIIP data, while in 2021 there was a positive dynamics of statistical indicators for filing applications for national registration of industrial property objects and issuance of protection documents (tables 2.19; 2.22), in 2022 there is a decrease in applications for national registration of industrial property objects (-59) and issuance of protection documents (-662).

Table 2.19. Information on applications received for issuance of protection documents for industrial property objects

units

Applications	**2020**	**2021**	**2022**	Share of applications in the total volume for 2022, %
Total	**13807**	**14421**	**13913**	100
Invention applications filed, total	900	805	838	6,0
national applicants	760	692	713	
foreign applicants	140	113	125	
Submitted applications for utility models, total	1109	1114	1109	8,0
national applicants	1054	1039	1057	
foreign applicants	55	75	52	
Applications for industrial designs filed	221	211	152	1,5
national applicants	84	89	71	
foreign applicants	137	122	81	
Trademark applications filed	**11533**	**12222**	**11742**	84,4
By national procedure	5596	6475	6960	
national applicants	3784	2021	5250	
foreign applicants	1812	1705	1710	
according to the international procedure	5937	5747	4782	
Applications filed for appellations of origin	2	5	6	0,0
national applicants	2		6	
foreign applicants	-		-	
Submitted applications for selection achievements:	**42**	**63**	**66**	0,5
Animal breeds	1	3	2	
national applicants	1	3	2	
foreign applicants	-	-	-	
plant varieties	**41**	**60**	**63**	
national applicants	23	42	42	
foreign applicants	18	18	21	
Topology of integrated circuits	0	1	0	0,0
national applicants	-	1	-	
foreign applicants	-	-	-	

Source: Annual Report of the National Institute of Intellectual Property

To characterize the level of inventive activity, the intensity of dissemination of national scientific and technological achievements, the degree of technological dependence of the country, the statistics use the coefficient of inventive activity, defined as the number of applications for inventions filed by domestic applicants with the country's patent office per 10,000 people.

Despite the annual increase in the number of applications filed with the patent office, the coefficient of inventive activity remains at approximately the same level (table 2.20).

Table 2.20. Coefficient of inventive activity

Innovation indicators	2018	2019	2020	2021	2022
Inventive activity coefficient (number of domestic patent applications for inventions filed in Kazakhstan per 10,000 population)	0,6	0,4	0,4	0,4	0,4

Countries of the world have the following data on this indicator: in the Republic of Korea - 33,05, in Japan - 20,39, Switzerland - 10,35, USA - 8,97, in Russia 2,05. Below the indicators of Kazakhstan in South Africa - 0,16, Mexico - 0,11*.

Source:*Calculated according to UNESCO Institute for Statistics (see: http://stats.uis.unesco.org) and WIPO (see: URL: http://www.wipo.int)

During the reporting period, the number of issued protection documents for industrial property objects, including international registration, amounted to 12 099, which indicates a decrease of 5,2% compared to the figure for 2021 (12 761).

The main share of applications falls on trademarks - 84,4%. This was facilitated, among other things, by the high activity of national applicants in the territory of the Republic of Kazakhstan. Thus, in 2022, 6 960 trademark applications were filed, including 5 250 by national applicants and 1 710 by foreign applicants.

In 2022, there was a 22,5% decrease in the number of applications filed under the Patent Cooperation Treaty (PCT) procedure. An even greater decrease in the number of applications filed under the procedure of the Eurasian Patent Convention (EAPC) - by 78% (table 2.21).

Table 2.21. Distribution of applications from national applicants for the issuance of protection documents for inventions filed under the PCT procedure and in accordance with the EAPC

units

Number of applications	2020	2021	2022
Filed under the PCT procedure	33	31	24
Filed under the EAPC procedure	91	81	18

Source: Annual Report of the National Institute of Intellectual Property for 2022

In recent years there has been a negative trend in applications for invention protection documents, but in 2022 the number of applications rose to 838 (2021 - 805) units. This was influenced by the increased activity of both foreign applicants, whose number of applications increased from 113 to 125, and national applicants - from 692 to 713.

It should be noted that among the national applicants, which received the largest number of patents for invention in 2022, are the universities of Kazakhstan:

NJSC «Toraigyrov University» - **30**; «KazNRTU» named after K.I. Satpayev - **27**; NJSC «Kazakh Agrotechnical University» named after Saken Seyfullin - **10**; NJSC «Almaty University of Power Engineering and Telecommunications» named after Gumarbek Daukeev - **9**.

Among foreign applicants who received patents for inventions by country of origin, Russia - 34; China - 22; USA - 17; Korea and France - 7 each, Japan - 5, the rest - one each. Total 112 patents.

The total number of utility model applications received in 2022 amounted to 1109 units, which is 23% less than in 2021 (1114 units). The number of granted protection documents for utility models amounted to 864, which is 0,5% less compared to 2021.

In 2022 there were 5,2% fewer applications for industrial designs (12 099) than in 2021 (12 761).

The total number of applications received for breeding achievements in 2022 exceeded the 2021 indicator by 3 points - 66/63. As in previous years, there were no applications for animal breeds from foreign applicants.

The number of protection documents issued in 2022 amounted to 12 099 (2021-12761) units.

For inventions, 585 (202 - 651) protection documents were issued, including 473 (2021 - 521) to national applicants and 112 (2021-130) to foreign applicants.

864 protection documents were issued for utility models (2021-1122), 176 (2021-177) for industrial designs, 39 (2021-47) for selection achievements, 6 (2021-44) for appellations of origin of goods, and 10 432 for trademarks, which is 3% less compared to 2021 (10,759) (Table 2.22).

Table 2.22. Information on issued protection documents for industrial property objects

units

	2020	2021	2022	Share of protection documents in the total volume for 2022,%
Issued protection documents for industrial property objects	12 016	12 761	12 099	100
Invention patents issued	709	651	585	4,8
Issued patents for utility models	1107	1122	864	7,1
Issued protection documents for industrial designs	177	177	176	1,1
Registered trademarks	9993	10759	10432	86,2
Registered appellations of origin	1	4	6	0,0
Protective documents issued for breeding achievements:	29	47	39	0,3
Animal breeds	–	–	–	–
plant varieties	29	47	39	0,3

Source: Annual Report of the National Institute of Intellectual Property

In the reporting year, the indicator of granting protection to trademarks (under national and international procedures) decreased by 57% compared to the previous year, amounting to 6 960 protection documents (2021 - 12222), including 5250 under the national system (2021 - 4770). Analysis of the data shows that compared to the previous year, the indicator of granting trademark protection under the national procedure increased by 480 units, while under the international procedure it remained at the same level - 1710 (2021–1705).

Compared to the previous year in 2022, the decrease in the number of protection documents of industrial property objects was observed for inventions ¬ by 5.2%. There is also a decrease in all other objects of industrial property, including a decrease in the number of issued protection documents for *utility models* (by 258 units, which is 23% less compared to 2021; *trademarks* (by 327 units, including international registration of trademarks - 10 432, which is 3% less compared to 2021 (10 759); *on selection achievements* by 8 units, 39, which is 17% less compared to 2021 (47); *on inventions* - 585, which is 10% less compared to 2021 (651); *on industrial designs* - 176, which is 1 unit less compared to 2021 (177); *on appellations of origin of goods* - 3, which is 25% less compared to 2021 (4).

Thus, the patent activity for 2022 in the republic as a whole decreased by 3.5%. Statistical data for 2022 show a decrease in the activity of registration of industrial property objects, which indicates that the authors of inventions are not interested in protecting the results of intellectual property. The share of utility model applications remains high, as evidenced by the fact that in 2022 on the factor «Development of technology and knowledge economy» in the Global Innovation Index Kazakhstan rose by 5 points - from **86 to 81 place**. Kazakhstan occupies competitive positions in the context of this factor by two indicators: the share of resident applications for utility models filed with the national patent office (1.6% of GDP) - **14th place** and the growth rate of real GDP per employed person on average over the last three years (2.2%) - **31st place**. (https://economy.kz/ru/Novosti_instituta/id=5262).

3. SUBSTANTIATION OF PRIORITY FUNDAMENTAL AND APPLIED RESEARCH (on areas of science determined by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan, and analysis of their implementation)

Priority I – «Rational use of water resources, flora and fauna, ecology»

1. *Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)*

Issues of climate change and progressive anthropogenic impact on the environment raise the need to take preventive measures to prevent the development of negative processes in nature and society at the global level.

The Republic of Kazakhstan, as an inland, highly arid country, is in a zone of increased water stress, which necessitates a systematic approach to the rational use *of water resources.* A significant part of the research on this topic is conducted at the JSC «Institute of Geography and Water Security» of the Scientific Committee of the Ministry of Education and Science of the Republic of Kazakhstan.

As a result of the implementation of a project on water security problems in the basins of the Transboundary rivers Ile and Ertis, a tool (simulation model, geoportal) was created to support decision-making in the field of strategic planning for the development of water supply systems according to the proposed system of water security criteria. A unique concept for ensuring the water security of the Republic of Kazakhstan has been developed and implemented in relation to the conditions of the Aral-Syr Darya basin, taking into account expected climate changes in water resources and economic activity [10–12].

«Passports of rivers of Kazakhstan» and «Passports of small lakes of Kazakhstan» were developed and implemented, in which the list of rivers with a length of more than 10 km was supplemented with identification and updating of names according to the catalog of geographical names of the Republic of Kazakhstan and a list of geographically identified small lakes, and the main hydrographic characteristics for identified natural watercourses using remote sensing data.

Scientists from the LLP Kazakh Research Institute of Water Management have carried out work on the assessment and forecast of annually renewable water resources that can be used for irrigation purposes in the water basins of the republic. Patterns of spatial distribution of river flow have been revealed. The nature of the spatial correlation of river flow has been studied as a basis for modeling its distribution over the territory. Irrigation technologies and technical means have been developed for the commissioning of new irrigation lands, the reconstruction and modernization of existing irrigation systems [13–17].

Significant research results on groundwater problems were obtained at the Institute of Hydrogeology and Geoecology named after U.M. Akhmedsafin at the NJSC KazNRTU named after K. Satpayev. An assessment was made of changes in the hydrogeochemical conditions of groundwater deposits in the western regions of Kazakhstan (Aktobe, West Kazakhstan regions) under climatic and anthropogenic influences [18,19]. As part of the program for scientific, methodological and geoinformation-analytical support for the rational use and protection of groundwater in conditions of climatic and anthropogenic changes, recommendations have been developed for solving problems of water supply to the territory of Kazakhstan, which include measures to regulate the natural recharge of groundwater; artificial replenishment of their reserves; water conservation; withdrawal of groundwater to enhance infiltration; a geoinformation-analytical system of groundwater resources has been created [20–23]. Significant resources of fresh groundwater have been identified, which are proposed to be used to cover the deficit in fresh drinking water in some territories of Western, Southern and Eastern Kazakhstan [24–26].

As a result of research conducted at ENU named after. L. Gumilyov, software schemes have been developed for a robotic complex for monitoring reservoirs in pre-flood and post-flood periods. This makes it possible to determine the qualitative and quantitative composition of natural waters and to predict the occurrence of chemical and physicochemical processes in the aquatic ecosystem [27–29].

The totality of the animal and plant worlds represents *biological resources* that are distinguished by a wide variety of communities. They create biomass and the appearance of the territory within their habitat.

In Kazakhstan, the leading scientific organization carrying out research on the diversity *of the animal world*, analysis and monitoring in preserving animal diversity and the balance between the sustainable development of society is the Institute of Zoology. Currently a national electronic data bank on the scientific zoological collection of the Republic of Kazakhstan with an information retrieval system has been developed, more than 25,000 records were entered into the database [30]. Work was carried out within the framework of the program for the cadastre of wild animals of the Northern Tien Shan. The fauna of the region was clarified, an electronic database was created and filled in with information currently available and collected during the project on 650 species of invertebrates, 250 species of vertebrates and 85 species of fossil animals. New species have been discovered for science and Kazakhstan [31,32]. New data on rare and endangered, as well as commercial animal species, the dynamics of population changes have been obtained, and predictive models for the distribution of rare species have been developed - snow leopard, brown bear, Turkestan lynx [33]. An inventory and assessment of the diversity of the insect fauna of the Tarbagatai State National Natural Park was carried out, a list of monitoring insect species was determined, and insect species new to science were described [34].

In the southeast of Kazakhstan, new data was obtained on the stopover and wintering areas of 14 bird species, including a rare species – the demoiselle crane (*Anthropoides virgo*); wintering areas in Africa, China, and Afghanistan were clarified [35]. More than 700 biological samples from 352 individuals of 51 bird species were taken for analysis for viral infections. A number of viruses (adenovirus, influenza type A, coronavirus, paramyxovirus) were identified in 13 bird species, and the role of birds in the transmission of viral infections was clarified [36].

Pelophylax ridibundus complex was determined based on the analysis of mitochondrial and nuclear DNA. Recommendations and measures have been developed to prevent the risk of expansion of invasive forms *of P. ridibundus* for the native amphibian fauna and regional fish farms. For the first time, screening molecular genetic typing of 64 samples from 33 points was carried out and 2 forms *of P.ridibundus were identified,* which in the future may receive an independent species status [37].

New knowledge has been obtained about the patterns of formation of tick foci in the Turkestan region and their role in the spread of diseases that affect population numbers [38]. To solve the problem of arachnosis, a new acaricidal drug has been developed [39].

An analysis of the seasonal dynamics of pollutants, the structure of phytoplankton, zooplankton, species richness of the supralittoral entomofauna and avifauna of the Sorbulak Lake system was carried out, and recommendations were given on the possible use of wastewater [40].

Forest resources are one of the most important types of biological resources, classified as exhaustible but renewable, multi-purpose. Research on the rational use of forest resources is the focus of the activities of the LLP Kazakh Research Institute of Forestry and Agroforestry named after A. Bukeikhanov. An assessment of the current state of the turangovniks of the south-east of Kazakhstan and the floodplain forests of the Zhaiyk River is given, information is provided on rare, endemic and relict representatives of the flora of the studied forest ecosystems [41,42].

For plant communities involving the endangered *Populus pruinosa* in the floodplain of the Ile River, the floristic composition has been studied in detail [43]. Proposals are given for the rational use of fir forests in Southwestern Altai and the conservation of relict Tugay forests in the Ile-BalKash region [44, 45].

For individual forest species – rare *Euonymus verrucosus*, *Corylus avellana* and economically valuable representatives of the genus *Spiraea* – clonal micropropagation technologies have been developed and generalized [46–48]. Essential oil components in the aerial parts of some forest species have been studied [49–52*]*.

The genetic parameters of economically valuable forest-forming species have been studied: the rare species *Malus sieversii*; *Picea schrenkiana*, as well as selection and genetic parameters in *Pinus sylvestris* [53–55].

A new direction in research on forest resources is the study of mycorrhizal macromycetes of the main forest-forming species (using the example of *Pinus sylvestris, Picea obovata, Betula pendula*), including in the area of the Ertis River in Central and North-Eastern Kazakhstan, which can be used as one of the means of increasing the sustainability of forest ecosystems [56,57]. The mycobiota of oak forests in the Zhaiyk River valley within the West Kazakhstan region was studied [58].

For artificial plantings of the green zone of Astana, the influence of thinning, including in young forests, with a set thinning intensity on the decorativeness and viability of such species as *Acer negundo* L., *Ulmus pumila* L., *Salix alba* L. and *Elaeagnus angustifolia* L. [59] was studied.

The Institute of Botany and Phytointroduction of the Committee of Forestry and Wildlife and Ministry of Ecology and Natural Resources of the Republic of Kazakhstan assessed the current ecological state of flora and plant resources in the Almaty region. An inventory of the species composition of flora and mycobiota was carried out for 6 administrative regions and Annotated lists of the flora of higher vascular plants, algae and mycobiota were compiled (2133 species from 644 genera and 110 families). A phylogenetic assessment of the region's vegetation was given based on 214 geobotanical descriptions, and a list of plant communities was compiled, combined into 9 types of vegetation. The locations of 40 rare species and 38 rare communities were determined and maps were compiled, for which soil conditions were characterized. The location of 42 alien species was identified and maps of their distribution by region were compiled. Knowledge has been expanded about the distribution, including through the introduction, of a rare forest species of Central Asia - *Aflatunia ulmifolia,* listed in the Red Book of Kazakhstan [60,61].

An assessment of the resource potential of economically valuable plant species was carried out and raw material reserves of 26 resource species were identified; commercial thickets are formed by 13 species: *Juniperus pseudosabina, Rumex tianschanicus, Berberis sphaerocarpa, Alhági, Rheum tataricum, Artemisia diffusa, Ferula soongarica, Salvia deserta, Thymus marschallianus Willd*, etc. [62].

As a result of the inventory of fruit forests, 35 forms of *Malus sieversii were selected* to replenish the collection of wild fruit plants of the Main Botanical Garden and Nursery of Wild Fruit Plants*,* and 26 forms of *Prúnus armeníaca* , which are of high value for breeding [63,64].

Created *in vitro at the National Center of Biotechnology* a collection of rare and endangered plant species of 150 specimens of *Berberis iliensis M. Pop*., 200 specimens *of Berberis karkaralensis*, 450 specimens of *Malus niedzwetzkyana*, 300 specimens of *Malus sieversii* for their use as a model for the conservation of other plant species, use in fruit growing, and landscaping [65,66].

in vitro collection (*A. altaicum, A. ledebouriamum, A. microdiction, Rhodiola rosea L.*) was also created. The collection will contribute to the in vitro preservation of valuable plant forms and their biological diversity [67].

A constant background for the development of human civilization is the threat of depletion and degradation of soil resources, which Academician G.V.Dobrovolsky called it «a silent crisis of the planet» [68]. It is estimated that every year about 12 million hectares of productive land become infertile due to desertification and degradation. Approximately 900 million people in more than 100 countries suffer from their consequences [69].

The rational use of soil resources is the subject of research by the LLP Kazakh Research Institute of Soil Science and Agrochemistry named after U.Uspanov. In recent decades, anthropogenic factors have become dominant in the development of desertification and soil degradation: within rain-fed arable land, 11.2 million hectares are subject to dehumidification, irrigated arable land - 0.7 million hectares, more than 30% of the soil area of irrigated arable land is saline, which leads to an increase in the area of saline soils, deserts. The leading type of desertification in Kazakhstan is the complex type (technogenic impact with degradation or complete destruction of the soil and plant layer) - 464.0 thousand km^2 (17%) of the territory of the republic [70].

Desertification is progressing in the irrigated zone of southern Kazakhstan, in large deltas and ancient alluvial plains in the Syrdarya and Ile river basins. Various soil types tended to become re-salinized with medium to high total salt content while increasing cadmium content due to contamination of irrigation water. Algorithms for compiling a salinity map based on remote sensing data have been developed, and the main predictor for decoding saline soils has been determined [71–75].

Research by the LLP Kazakh Research Institute of Forestry and Agroforestry named after A. Bukeikhanov has developed measures to prevent desertification and land degradation using black saxaul in the desert zone of Kazakhstan [76].

To desalinize soils at various groundwater mineralizations in southern Kazakhstan, LLP The Kazakh Scientific Research Institute of Water Economy (KazSRIWE) developed and implemented an innovative technology on an area of 2000 hectares [77].

In soil degradation, erosion occupies a large segment and it is possible to assess its development based on modeling using the universal soil loss equation (RUSLE) using GIS technologies and satellite data. This kind of research was carried out at the ENU named after L. Gumilyov for the conditions of the West Kazakhstan and North Kazakhstan regions. This made it possible to calculate average annual soil losses and identify areas with high rates of leaching [78–80].

A new direction in soil resource research is soil health. Research by West Kazakhstan Agrarian-Technical University named after. Zhangirkhan conducted studies of microbiocenoses of anthropogenically disturbed saline soils in Western Kazakhstan at the level of metagenomic testing. Bacteria that are specific and resistant to critical conditions have been discovered in soils, which makes it possible to develop qualitatively new, highly effective biotechnologies on their basis [81].

For the ecology of Kazakhstan, a serious problem is the dried bottom of the Aral Sea. Research has established that on the dry bottom of the Aral Sea, peculiar soil formation processes occur, the general pattern of which is their weak development against the background of strong initial salinity and carbonate content, and soil types have been determined [82], and methods for creating reclamation plantings for various soil conditions and mechanical composition of degraded soils may be one of the options for saving water in the irrigated region of the Aral Sea basin [83].

Searching for techniques and methods for recycling wastewater, including reuse for economic purposes - solving an environmental problem for industrial agricultural complexes, large cities, etc. Significant results in this direction have been obtained at ENU named after L. Gumilyov [84, 85].

Another pressing issue of modern ecology is the quality of atmospheric air, especially in large cities. Thus, research from KazNU named after Al-Farabi, using the example of the capitals of Central Asian countries, shows that the main source of pollution is transport, but a significant share is also allocated to emissions from thermal power plants and private houses using solid fuels. Scientists have recommended proposals for policymakers to take effective measures to mitigate the effects of pollution [86,87].

2. *Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations*

Global scientific trends on water resources cover the areas of research on forecasting water availability and quality in glacier basins, climate change, water resources in the context of food security, which are carried out by the Institute of Geography and Water Security together with foreign centers at the University of Reading, United Kingdom; Central Asian Institute of Applied Geosciences, Kyrgyzstan; Institute of Water Problems, Hydropower and Ecology, Tajikistan; Institute of Geology and Geophysics named after Abdullaev and Scientific Research Institute of Hydrometeorology, Center for Hydrometeorological Service of the Republic of Uzbekistan, etc. In matters of integrated hydrological and water management modeling to solve problems related to the management of water resources of river basins, breakthrough research is carried out by the Danish Hydraulic Institute; Center for Hydrological Engineering, USA.

The global development trend in the field of animal life is to provide the ability to assess the degree of danger of zoonoses, with the creation of national epizootic surveillance programs. Another applied aspect of zoology is the study of animal venoms (venomics). In Kazakhstan, as well as in the world, there is interest in the *Panthera tigris tigris revival program*. The World Wildlife Fund (WWF), together with the Institute of Zoology, is implementing grants in Kazakhstan to revive its population. Under the UNDP project, research was carried out on the development of zoning and landscape planning schemes for the sustainable management of key biodiversity zones using the example of the Almaty region.

Modern trends in the development of research on the rational use of soil resources are the assessment of soil quality in its full concept, the development of models for global assessment of soil degradation similar to ASSOD, GLASSOD, MEDALUS, LADA, IMDPA, RALDE, and the use of hyperspectral technologies [79–82]. An important trend in research on soil ecology is the problem of soil pollution with microplastics, which increases soil temperature, affecting its biota, increasing the effect of greenhouse gases [83]. The problem of microplastics is also important and relevant for the aquatic environment, since it is of national interest in the field of preserving and improving the ecological environment for the future [84].

A large number of studies were carried out with the Xinjiang Institute of Ecology and Geography of the Chinese Academy of Sciences on the integrated management of natural resources in drought and salinity-prone agricultural landscapes of Central Asia, on the introduction of sustainable soil management methods to improve the condition of saline soils.

The most current global trend in forest science is research into the surrounding forest environment: climate, soil, ecology, fires, pests, diseases and biodiversity [85–87]. A close focus is on coniferous forests, research on post-fire succession, the process of natural regeneration depending on the intensity of the fire, and the environmental consequences of forest fires using mathematical modeling methods [88,89].

Of particular scientific interest are studies on the ecological restoration and management of the mountain-river-forest-agricultural land-lake-meadow system in the Ertis River basin in Altai, Xinjiang; according to the characteristics of surface evapotranspiration in the Ile River basin.

Much attention in the world is paid to research on forest products (wood and non-wood), including secondary metabolites [90–92].

Successful examples of cooperation between domestic scientists and foreign ones in the field of forest resources research are joint projects with specialized centers of the CIS countries, with the Asian Forestry Cooperation Organization (AFoCO), the Korean National Arboretum, the Xinjiang Institute of Ecology and Geography of the Chinese Academy of Sciences on the study of the resistance of black saxaul forms to insects - gall formers, on scientific expeditions in the study of forests of the Tien Shan, etc.

A large amount of work and research in the field of botany and phytointroduction is carried out within the framework of international programs: monitoring of green and protective forest plantations in the Aral region together with the Kazakh-German University; regional strategy for drought risk management and mitigation of its consequences with REC CA/UNCCD; environmentally oriented regional development of the Aral Sea region: monitoring of wetlands of the Small Aral Sea and the Syrdarya River delta together with the German Society for International Cooperation (GIZ), etc.

In the field of research of animal and plant resources, and soil resources, modern research methods are used - methods of molecular genetic analysis, which allow us to look at the most subtle levels of the organization of life; remote methods, for example, methods of telemetric recording of animals, GIS analysis methods, remote sensing, cloud technologies, mathematical modeling, etc.

Recently, metagenomics has been developing rapidly; areas such as GIS modeling of habitats in the light of climate change have received significant development.

3. *Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries*

Achievements and development trends of leading scientific schools of Kazakhstan in this area were mainly reflected in section 1.

Scientific schools on *water issues* formed in organizations such as «The Institute of Geography and Water Security» of the Scientific Research Institute of Water Resources of the Republic of Kazakhstan, LLP «Kazakh Research Institute of Water Management», Institute of Hydrogeology and Geoecology named after U.M. Akhmedsafin at the NJSC «KazNRTU» named after K. Satpayev are focused on solving pressing problems of water supply in environmentally unstable regions of the republic and transboundary rivers; development of a new scientific direction for vacuum hydrocyclone purification of natural waters from sediments; improving the operation of irrigation and drainage systems; solving problems of water and salt balance on irrigated lands of Kazakhstan; research of groundwater resources, environmental problems of aquatic ecosystems, modeling of hydrodynamic and geoecological processes, etc. The world's leading scientific schools on water resources with research on improving water management in order to ensure food security and reduce poverty while maintaining vital environmental processes, to solve problems in water purification through the application of nanoscale science and technology operate at Rice University, University of Texas (USA), International Institute of Water Resources Management (Sri Lanka), Institute of Water Problems of the Russian Academy of Sciences (Russia).

The most important modern research *of the zoological school* of the republic is carried out at the Institute of Zoology of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan. This is the study of bird migrations, ecology of mammals, paleozoology and parasitology, elucidation of life cycles, ecology and morphology of helminths of animals in Kazakhstan, focality of diseases, entomofauna, study of amphibians and reptiles, hydrobionts and ecotoxicology. Among foreign scientific schools, it should be noted the German Research Institute for Zoological Systematics (Munich), the Kazan Zoological School with research on the biology of bioinvasive species in ecosystems, *the evolutionary and functional morphology* of animals, etc., the Japanese scientific school (Okayama, Hiroshima, Tokyo universities) with research on vertebrates and crustaceans.

Long-term comprehensive research on the study of the forest fund of the republic was the basis for the creation of a scientific school *on forest resources* on the basis of the LLP Kazakh Research Institute of Forestry and Agroforestry named after A. Bukeikhanov - the study of forest ecosystems and their individual components in various natural zones of Kazakhstan, the study of rare, located endangered and economically valuable forest species, development of the theory and practice of carrying out landscaping and agroforestry activities in the republic, etc. In the world, *scientific schools on forests* exist in almost every country and the main emphasis is on research on sustainable management of forests and natural resources: Ontario Forest Research Institute (Canada), Finnish Forest Research

Institute, Forest Institute of the Russian Academy of Sciences (Russia), Forestry Research Institute of Sweden, Research Institute of Nature and Forests of Belgium, etc.

Founded in the 30s of the last century, the scientific school for *the study of plant resources* of Kazakhstan successfully continues the traditions at the Institute of Botany and Phytointroduction of the Ministry of Energy and Natural Resources of the Republic of Kazakhstan. Modern areas of research are the preservation of the plant gene pool, the introduction enrichment of the gene pool of botanical gardens, the development of scientific principles for the balanced use of plant cover and plant resources, etc. Research in the field of conservation and replenishment of the gene pool of plant resources, introduction and selection of plants is also complemented by the scientific schools of the Institute of Biology and Biotechnology, National Center for Biotechnology. Among the foreign schools, the scientific school of gradient analysis and vegetation ordination (University of Wisconsin) and the school of vegetation mapping (University of Kansas) still stand out.

The foundations of research in botanical science, laid in the 18th – 19th centuries in European countries, continue to be developed in schools at the University of Hanover, the Stolzenau Center for Vegetation Research (Germany), the International Geobotanical Institute of Mediterranean and Alpine Countries (France), etc.

Soil degradation processes associated with salinization, dehumification, pollution with heavy metals, waste from industrial activities – subsoil users, household waste, soil health, carbon sequestration – the object of research of the Scientific School of soil scientists, represented by the LLP Kazakh Research Institute of Soil Science and Agrochemistry named after U. Uspanov, as well as scientists from foreign countries: Leibniz Institute of Soil Science Hannover University (Germany), Alberta University (Canada), University of North Dakota (USA), Xinjiang Institute of Geography and Ecology of the Chinese Academy of Sciences, Soil Institute named after V. Dokuchaev, Research Institute of Soil Science and Agrochemistry of the Hungarian Academy of Sciences, etc.

Priority II – «Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technologies, safe products and structures». Section «New materials and technologies»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

Modern science and technology are developing very dynamically. Materials science is a critical element in the development of new products. This discipline sits at the intersection of engineering, physics and chemistry and is critical to advancing product design and manufacturing. Knowledge of materials science can help manufacturers create better products with unique properties that give them an edge over their competitors. Scientists in Kazakhstan conduct a lot of scientific research on the synthesis and use of new materials.

In the field of new materials and technology: at *Nazarbayev University* researchers, using chitosan as a raw material, by successfully adding carbon quantum dots (CQDs) and silver sulfide (Ag2S), synthesized a composite containing chitosan/Ag_2S/CQDs (CS/Ag_2S/CQDs hydrogels), which can be used as an adsorbent with antibacterial properties [93];

A study of superhydrophobic SiO_2 /trimethylchlorosilane coatings for self-cleaning application to building materials was carried out . This study was the first to demonstrate the potential application of coatings to protect brick or architectural structures from harmful weather conditions using a self-cleaning method [94];

Terbium- and barium-doped mesoporous silica nanoparticles with improved optical properties have been studied. This study shows for the first time that co-doping with barium (Ba) improves the luminescence properties of terbium (Tb)-doped $SiO_{2\ nanoparticles}$ [95,96];

Satbayev University is conducting research into a revolutionary new water treatment technology capable of removing microplastics, including microfibers, from drinking water sources and wastewater by using cold plasma in combination with activated carbon [97];

Research was carried out to develop a technology designed to process dust from the electric smelting of ilmenite concentrate with the extraction of silicon and titanium and the production of products in the form of their dioxides. A technological scheme has been proposed for the complex processing of dust from the electric smelting of ilmenite concentrates to produce silica and 99.8% titanium dioxide (TiO2) [98];

Finding the most effective integrated technology for extracting gold from minerals is an urgent task for the gold mining industry of Kazakhstan. This technology for processing gold ore was developed using chemical, X-ray diffraction, mineralogical and X-ray fluorescence analyses [99];

The dependences of the physicomechanical properties (hardness H, elastic modulus E, resistance H/E elastic deformation and resistance H^3/E^2 plastic deformation) of samples of matrices made of cobalt (Co) hard alloy with different contents of chromium diboride in composite diamond-containing materials obtained cold pressing method followed by vacuum hot pressing, according to the results of nanoindentation [100];

A study was carried out to solve the problem of processing slag obtained as a result of hot-dip galvanizing of products, in particular, waste-free disposal of its oxidized component by chlorination by firing using cheap chlorine-containing reagents $CaCl_2$ and NH_4Cl. It has been established that at a firing temperature of 1000°C, thorough sublimation of impurities is achieved, which ensures the production of pure zinc oxide, suitable for use as a mineral additive in feed for animals and birds [101]; a study was carried out of the effect of lanthanum doping on the processes of phase formation in ceramics based on $CaTiO_3$, as well as an assessment of the effectiveness of ceramics as photocatalysts for the decomposition of the organic dye rhodamine B. When determining the photocatalytic activity, it was found that the formation of the La0.3Ca0.7TiO3 phase leads to an increase in the rate of decomposition, as well as the degree of mineralization [102,103];

At the Al-Farabi Kazakh National University, research was carried out on the development of a waste-free technology for the production of aluminum borides using the method of self-propagating high-temperature synthesis (SHS), which makes it possible to obtain target (alloy) and by-products (slag) that meet the requirements for chemical and phase composition. High-alumina clinkers are used in the production of cement used for refractory concrete lining of furnaces of metallurgical, chemical and engineering enterprises, as well as in the production of building materials [104];

Metalloporphyrin-containing mesoporous materials, called VTPP@SBA, were prepared by simply anchoring vanadyl porphyrin through a mesoporous material such as SBA - 15. For comparison, vanadyl porphyrin was also impregnated with silica SiO_2 (VTPP/SiO_2). This is the first time that V-porphyrin-derived materials have been tested for photoelectrochemical applications, showing good potential for this application [105]. Based on NiO nanoparticles, PAN/NiO composite fibers were obtained by electrospinning. The resulting composite fibers were modified through heat treatment processes (stabilization and carbonization). It was shown that the resulting composite fibers could be used to detect acetone and acetylene in air. These results indicate that C/NiO-based electrospun fibers have potential applications in gas sensors [106];

Luminescent carbon nanoparticles containing O,N (O,N – CNPs) were synthesized by a one-step method. (O,N) – CNPs are promising materials for biomedical applications as fluorescent probes with high sensitivity to acids due to high stability and high fluorescence intensity in a complex aqueous matrix. To this end, polymer hybrid hydrogels for wound dressings have been modified with (O,N) – CNPs [107];

The characteristics of NO2 gas sensitivity at room temperature (RT) of hybrid nanocomposites with an interpenetrating mesh using TiO2 nanoparticles decorated with reduced p-phenylenediamine graphene oxide (PrGO) were investigated. The strategy and results of this work shed new light on the use of various functional materials for highly sensitive gas sensors in RT [108];

At the Euro-Asian University named after L.N. Gumilev, the structural, magnetic and optical properties of mesoscale particles in the form of layered Au/Fe/Au disks and Ni@Au nanotubes were studied. Ferromagnetic structures coated with plasmonic metals demonstrate high photothermal conversion efficiency in the plasmon resonance region. Together with their magnetic properties, such as the vortex magnetic state, these structures are promising for biomedical applications [109];

Experiments have been conducted to relate the structural parameters of porous silicon (PS) to the morphology of gold nanostructures fabricated on its surface, focusing on the surface-enhanced combined scattering response (SERS) [110];

Effective methods and advanced materials have been widely developed for the removal of highly toxic organic pollutants, including pesticides. This study investigated the photocatalytic degradation of the fungicide carbendazim (Czm) using track-etched composite membranes (TeMs) in aqueous solution [111];

A technology has been developed for the synthesis of nickel oxide crystallites and nanocrystallites on the surface of indium phosphide. This technology consists of two stages. At the first stage, porous indium phosphide is formed on the surface of an indium phosphide single crystal. Such structures can find promising applications in electrochemical capacitors and lithium-ion batteries [112];

An APt-free nickel-copper sulfide (NCS) ternary nickel-copper sulfide (NCS) electrocatalyst has been investigated *at the Kazakh-British Technical University (KBTU) for iodide/triiodide electrolyte reduction in dye-sensitive solar cells.* Electrochemical impedance analysis revealed comparable electrocatalytic activity of NCS to that of Pt [113];

Carbon nanomaterials (CNMs) containing platinum: fullerenes, nanocomposites, graphenes, single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWCNTs) were created by the plasma-chemical synthesis of MPG-7 graphite in a helium environment using a catalyst (Pt) [114].

2. Review and analysis of global trends in the field of materials science, examples of cooperation between domestic scientists with foreign scientists and work performed under an agreement with international scientific organizations

International cooperation in Kazakhstan with materials science is at a high level. International grants are won, scientific research is conducted from internships, scientists make presentations at international conferences, foreign scientists are invited for joint research, and training of masters and PhDs in foreign scientific and educational centers. Each advanced scientific group has a fairly large number of foreign partners. An indicator of international cooperation can be serve as joint publications.

Almost a third of publications were published jointly with Russian scientific centers, more than half are with CIS countries, which is not surprising, since many scientific schools have roots in Russia and Ukraine. On the other hand, collaborations with centers in the USA, Europe are showing good growth, China, India, Japan and South Korea. Regarding specific projects, we can note the international NATO project «G5636 – Valorization of biomass waste into highly effective materials for protection against CBR», implemented in the period 2019–2022 and the successfully completed RSE at PCV by the «Institute of Combustion Problems» together with the «Royal Military Academy» (Brussels, Belgium), within the framework of which highly effective carbon sorbents were synthesized and the sorption properties of toxic gases were studied [115]. You can also note the won international project «Horizon Europe» in the current year 2023 by Satbayev University together with foreign collaborators, where research will be carried out in the field of purification of both drinking water and wastewater.

3.Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

One of the qualitative characteristics of the general development and potential of a particular scientific direction is the state of scientific schools.

The School of Materials Science and Green Technologies (SMaGT) was created at the Kazakh-British Technical University on the basis of the Laboratory of Alternative Energy and Nanotechnologies (LAEaN) and the Laboratory of Advanced Materials and Technologies (LAMT).

The scientific school «Synthesis of Nanomaterials in Flames» was created at the Institute of Combustion Problems under the leadership of Professor Z. Mansurov.

According to the QS World University Rankings by Subject 2023, the best 10 scientific schools in the field of materials science around the world are:

- Massachusetts Institute of Technology (MIT) , Cambridge, USA;
- Stanford University , Stanford, USA;
- University of Cambridge , Cambridge, United Kingdom;
- Harvard University , Cambridge, USA;
- University of California at Berkeley (UCB) , Berkeley, USA;
- Nanyang Technological University, Singapore (NTU Singapore) , Singapore;
- EPFL , Lausanne, Switzerland;
- Imperial College London , UK;
- Tsinghua University, Beijing, China.

To support competitive scientific schools, the principle of competitive distribution of public finances should be more widely implemented, and for this it is necessary to know and evaluate their condition.

Priority III – «Energy and mechanical engineering». Section «Mechanical Engineering»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

Mechanical engineering is one of the indicators showing the level of development of the country, the intellectual capabilities of the population, the level of education, etc. In developed countries, the share of engineering production is 30–50% of the total industrial output (Germany - 53.6%, Japan - 51.5%, Great Britain - 39.6%, Italy - 36.4%, China - 35.2 %) [116]. In Kazakhstan, the mechanical engineering industry accounts for 1.5% in the structure of gross domestic product (GDP), in industry it occupies 6%, and there are about 4 thousand enterprises. At the last XI Forum of Mechanical Engineers of Kazakhstan, a decision was made to develop a program for the development of mechanical engineering for the next 5 years. In 2022, the Ministry of Industry and Infrastructure Development (MIID) created groups for the mining and metallurgical, electrical, oil and gas, railway, and agricultural engineering industries [117].

In world practice, mechanical engineering is the main element of the technological development of the economy, the growth of the manufacturing industry and the well-being of the population. Metallurgy remains the largest manufacturing sector in Kazakhstan. To increase the sustainability of the economy, it is necessary to move away from raw materials production to production with a high share of added value, with the most efficient production being mechanical engineering [118]. Data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan on the mechanical engineering development index since 2015. as a percentage compared to the previous year indicate that mechanical engineering does not have a steady upward trend; indicators have been growing since 2017, but not evenly; it is also necessary to take into account inflation and rising product prices [119] (table 3.23).

Table 3–23. – Mechanical Engineering Development Index

Years	2015	2016	2017	2018	2019	2020	2021
Mechanical engineering	70.8	84.7	109.2	114.4	124.1	116.4	122.2
Car production	45.2	63.3	138.8	117.4	168.8	158.3	121.8

The most notable mechanical engineering projects include the joint plant for the production of diesel locomotives «Evolution» of the General Electric Company (USA) in Astana, the annual production program is 100 diesel locomotives, the cost of one diesel locomotive is about 8 million US dollars. Currently, the graduation program has been reduced [120]. In 2010, a joint plant with Spain for the production of Tulpar-Talgo cars was launched, with a design capacity of 150 cars per year. Currently, the plant has been taken over by a company from Switzerland, and production volumes have decreased [121].

Scientific research is necessary for the development of mechanical engineering. In 2017–2022, under the scientific priority «Energy and Mechanical Engineering", 449 projects were approved for financing in 22 competitions, including GF-405, PCF-39, GK-5. The number of approved projects out of the total number of submitted projects for competitions is 44%. Over the past three years, 169 projects have been completed, the reports of which were approved by the NSC, of which more than 70% are projects in the «Energy» direction, less than 30% in the «Mechanical Engineering» direction. The same ratio holds for the total number of approved projects for 2017–2022. During this time, only 5 projects for commercialization were considered, of which only one project was in mechanical engineering. This analysis indicates that the scientific, technical and technological support of the country's mechanical engineering industry is also not in the best way; there are practically no implementation projects [117,127].

Scientific developments in mechanical engineering are carried out mainly in higher educational institutions. The largest technical university in the country is the Kazakh National Technical Research University named after K. Satpayev. One can note the work of Prof. Tusupbekova M.R. in the field of automation of production processes and planning of equipment placement in the workshops of the enterprise.

Prof. Mendebaev T.M. worked on the development of stabilizing technology for cutting products. The purpose of the work is to obtain processing modes and conditions under which the smallest changes in the shape and size of the product occur after processing. Prof. Povetkin V.V. worked in the field of designing efficient machines, in particular the design of a centrifugal submersible pump, a burner for cutting stone and optimizing the parameters of gears. Prof. Mashekov S.A., Absadykov B.N. dealt with the creation of rolling mills with high quality parameters [122]. Prof. Askarov E.S. deals with the creation and design of new machines, in particular, a fundamentally new cam-screw press has been created, which has significant advantages over existing crank presses. A new design of a wind power plant (WPP) with a fixed vertical axis has also been proposed, which has significantly simplified the production and cost of such wind turbines. A new design of a centrifugal gyratory mill has been created for grinding mineral raw materials with reduced energy consumption and a high level of grinding. Based on the presented developments, samples were manufactured that passed successful tests [123].

Pavlodar State University named after. S. Toraigyrov. Scientific work is being carried out in the field of mechanical engineering, in particular the design of a wind power plant (WPP) and the development of new resource-saving cutting tools for processing holes. These are the works of Prof. Dudak N.S., Abisheva KK, Kasenova A.Zh., Mukanova R.B., Shumeiko I.A. The university publishes its own journal on mechanical engineering, « Science and Technology of Kazakhstan» , which is included in the CQAFSHA list [124]. *Karaganda Technical University named after. A. Saginov*. Work is underway here in the field of increasing the resistance and durability of equipment in the mining industry, and the technology of processing hard steels and materials. Prof. Sherov K.T., Zhetesova G.S. are working in this direction [125]. *Kazakh National Agrarian Research University.* At the Department of Mechanical Engineering, prof. Zhunisbekov P.Zh. works in the field of research and improvement of agricultural machinery designs [126].

Institute of Mechanics and Machine Science named after. U. Dzholdasbekov. Work is being carried out to study the theory of mechanisms and machines, new schemes are being developed, their synthesis and calculations are being carried out. Prof. Tuleshov A.K., Ibray S.M., Seydakhmet A.Zh., Dzhomartov A.A. They are developing designs for an oil pump with reduced metal consumption, a pantograph lift with increased efficiency, robotic equipment for use at KazAtomprom enterprises, robots for hospitals, etc. [127].

In Kazakhstan, work is underway to create wind turbines. This work was carried out by the National Agrarian Center, where the « Romashka» wind turbine was created and several prototypes were manufactured. Quite active work was carried out on the creation of wind turbines with a vertical axis of rotation of the rotor. A design of a carousel rotor with a guide frame was proposed by Bolotov A.V. This scheme had a high metal consumption. Buktukov N.S. worked in the field of creating a rotor with folding blades in hurricane winds, but this property of wind turbines is not the main one. Ershin Sh.A developed a double rotor Darier, where the blades rotate in different directions. This solution increased the efficiency, but the design of the wind turbine turned out to be complex and significantly increased its cost [128].

2. *Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under agreement with international scientific organizations*.

Main trends in the development of mechanical engineering in the world:

1. Increasing the cutting speed by increasing the hardness of the cutting tool and the rigidity of the machine components, which reduces the manufacturing time of the product and increases the productivity of the process. Special materials based on metal ceramics with very high hardness are being developed, which makes it possible to efficiently and quickly cut hard alloy steels, titanium and alloys [129].

2. Development of the capabilities of numerically controlled machines. Increasing the level of flexible adaptive automation through the use of computer control using powerful software covering the entire process of creating a product from the design stage to the manufacturing stage (CAM/CAD system). The possibility of self-learning of the machine, the control system of which remembers the technology for manufacturing parts and in the future, when a similar part appears, uses the technology from memory to a new part. The ability of machine control systems to quickly share technological information with each other.

Creation of universal multi-purpose machines capable of operating in different modes, such as turning, milling, drilling, boring, gear cutting machines, etc. Simplification of the kinematics of machine tools, replacement of mechanical connections and control elements with computer control for coordinating the mutual movements of the working parts of the machine. Creating a machine self-diagnosis system that allows you to quickly, automatically change processing conditions and modes depending on the operating situation, prevents machine breakdown, and does not allow the machine to produce defects.

Flexible manufacturing systems (FMS) are a system of several CNC machines, workpiece loading and product unloading equipment. This system allows the CNC machine to operate for a long time without human presence. The GPS automation system includes, in addition to cutting control elements, a self-diagnosis system, a system for responding to emergency situations, self-adjustment, selection of the optimal choice of processing modes, etc. Example - GPS series INTEGREX - MAZAK. This GPS can operate continuously, without human presence, for 720 hours (30 days). This system does not require light, heat, fresh air, etc. [130].

3. Development of additive technologies. This is a fundamentally new type of processing in mechanical engineering. If before this the processing was carried out by removing excess metal from the workpiece (subtraction), here, on the contrary, powder or resin is supplied to the processing zone, and the laser beam, selectively heating certain places, forms a given product. The process of adding material to the part occurs. Currently, many varieties of this technology are known. Mechanical engineering mainly uses SLS technology (Selective Laser Sintering).

Advantages of additive technology: manufacturing products of complex shapes with voids; use of different materials without mixing; light cellular structures; micro- and nanostructuring of the surface; the designer can offer any surface in his project - he is less bound by technological restrictions.

Disadvantages: low precision in manufacturing parts; no interchangeability; products created using the same program can have quite different sizes; low speed of the process; high roughness; anisotropy of properties, that is, different properties of a product depending on the direction of the load; the density of the material may be insufficient and heterogeneous; high residual stresses and uneven heating of the product during the formation process create residual stresses and deform the product [131].

4. Development of methods for creating computer-aided design (CAD) systems for machines. Currently, many computer programs have been created for designing machines - primarily Autocad, Compass, Solidworks. A computer design program gives the designer many opportunities: drawing speed, memorizing drawings, creating basic modules of units that can be used in other drawings, storing drawing information for a long time and issuing this information at any time, transferring drawings by e-mail to any place, fast transformation of existing drawings into other projects with changed parameters, simple scaling of structures for changed technical parameters, etc. Graphic programs greatly simplify and speed up the drawing process. For the strength calculation of a machine, there are many computer calculation programs, for example, ANSYS.

5. Development of machines with high speeds of movement and rotation of working bodies, which requires equipment and technologies for precision processing with high accuracy. These are ground vehicles, aircraft, centrifuges, separators. There is a constant need to increase machine speeds. For example, a modern railway locomotive can reach speeds of up to 500 km/h. Vehicle speeds increase. It is necessary to develop separators with high rotation speeds up to 100,000 ^{rpm} . In high-speed machines, it is necessary to take into account the influence of dynamic forces; the manufacture of parts and assembly requires high precision.

6. Development of technologies for processing curved profiles. In some mechanical engineering products it is necessary to use curved profiles. These are mainly objects that interact with liquid or gas, in particular the blades of ship propellers, hydraulic turbines, aircraft turboprop engines, rocket nozzles, etc.

7.Development of technologies for restoration and repair of machines. Recently, the processes of repairing machines and equipment have become of great importance in mechanical engineering. This is due to a number of factors.

Improving the quality of repair technologies. New technologies have emerged for restoring parts, increasing the strength of the surface layer, reducing friction in mating parts, new modern materials, more reliable coatings against corrosion, etc.

Increasing environmental regulations have significantly increased the cost of many new products, especially those manufactured in industrialized countries that have very stringent environmental laws and standards. Increasing complexity of machines also increases their cost. Science and technology are now creating such complex and expensive machines that, purely for economic reasons, their service life should be quite long. This applies to large mechanical engineering projects.

8. *Development of robotic manipulators.* Robotic manipulators are widely used in mechanical engineering. These are complex machines; in general, they are a multi-link structure with several degrees of freedom and drives. Such manipulators are used in assembling machines, painting, welding, manufacturing small objects with complex profiles, for example, microcircuits, etc. Requirements for the mechanics of the manipulator - positioning accuracy, speed of movement, reach of the object's working area, execution of a given trajectory of movement, etc.

9. *Development of new machines and mechanisms***.** Inventive work is underway to create new machines that have higher quality indicators compared to analogues. Scientists must develop new machine designs based on the theory of mechanisms that have better performance, consume less energy, do not pollute the environment, are more convenient and safe for humans, etc.

10. *Development of the theory of enterprise and personnel management.* Scientific research in the field of management and organization of mechanical engineering production is being developed. Globalization is increasing competition in the sales market; in order to be at the top of success, it is necessary to apply the most modern methods of organizing and managing production. In the work of personnel, it is necessary to apply the methods of Lean Manufacturing, Kaizen, Total Quality Management, etc. [132].

An example of effective cooperation with foreign scientists in the field of mechanical engineering is the activities of Pavlodar State University named after S. Toraigyrov. The University has concluded agreements on scientific cooperation with the Czech Technical University, the University of Castilla (Spain), and the Polytechnic University of Marche (Italy). In 2021, an agreement was concluded with the Anhalt University of Applied Sciences (Germany), within the framework of which professors from this university Mark Eckman and Eduard Simmens visited Pavlodar, as a result, a program of general research in the field of mechanical engineering was adopted, in particular the development of cutting tools for machine tools .

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries.

The scale of scientific research by Kazakhstani scientists in mechanical engineering leaves much to be desired.

The 8 priority areas of the engineering industry (automotive engineering, electrical equipment, agricultural engineering, railway engineering, oil and gas engineering, mining engineering, space technology and technology, defense engineering) account for 12 projects each over the past seven years, or no more than two projects per year, which is extremely not enough.

There are practically no implementation projects. This is explained by the small number of high-tech mechanical engineering enterprises in the country and the small number of mechanical engineering enterprises in the country.

At the same time, Kazakh scientists are implementing projects on popular topics that correspond to global trends in the field of mechanical engineering and robotics. This is evidenced by the dynamics of publications of mechanical scientists in highly rated journals and the patenting of their results in Kazakhstan and abroad. Thus, over the past 5 years, only by mechanical scientists from the Institute of Mechanics of Machine Science named after U.A. Dzholdasbekov., more than 140 articles in highly rated journals have been published, 138 inventions have been patented in the Republic of Kazakhstan, 29 in the Eurasian Patent Community and foreign countries.

At the same time, in recent years, many manufacturing enterprises have shown interest in cooperation with scientific organizations and are willing to enter into consortium agreements, including with foreign organizations. An example is the consortium cooperation between IMMS named after U. Dzholdasbekov, KazNITU K.I. Satpayev, LLP KARLSKRONA LC AB (Kazakhstan) and JSC «Nasosenergomash Sumy» and OJSC AUSRINPPE (All-Union Scientific Research Institute of Nuclear and Power Pump Engineering) (Ukraine) for the implementation of scientific and technical progress «Development, application of scientific and technological methods and digital tools to increase the productivity and competitiveness of pumping industry in Kazakhstan at the level of Industry 4.0» within the framework of the PTF for 2022–2024. Scientific and production cooperation and R&D are being developed between IMMS named after U.A. Dzholdasbekov, LLP SaryarkaAutoProm (Allur) [127].

In many foreign countries, mechanical engineering is the main engine of the economy. Huge financial resources are being invested in it by both the state and private firms. All advanced countries invest huge amounts of money in mechanical engineering, because in the modern world, the biggest profits come from information technology and mechanical engineering. Developments are being carried out in the field of transport engineering - these are airplanes, railway locomotives and cars. Power engineering – turbines, generators, electric motors, wind turbines. Mining and metallurgical production, agricultural machinery, oil and gas equipment. The leading countries in mechanical engineering science are currently the USA, Germany, Japan, and the South. Korea, Italy, France, Sweden, and China and Taiwan have recently joined [133].

Priority IV – «Information, communication and space technologies»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

1. Information technology. As part of the National Digitalization Project, the Head of State set the task of training at least 100 thousand highly qualified IT specialists by 2025 [134–135].

The defining prospect for developing the country's informatization is the development of unique information products and technologies with trained IT specialists of the new generation.

Implementation of the «Smart Bridge» project. In March 2020, the Smart Bridge integration platform was put into commercial operation, providing a simplified procedure for integrating various information systems.

In pilot mode, a mobile version of the new system was demonstrated for the Presidential Administration in the «Aitu» application; work is underway to finalize and launch it into commercial operation.

In accordance with the instructions of the Head of State, the Ministry of Digitalization is working to transition to a new platform model, which will become the basis for large-scale digital transformation in the Republic of Kazakhstan [134–135].

2. Telecommunication technologies. Kazakhstan has two telecommunication spacecraft in geostationary orbit to solve the problems of the telecommunication systems industry in Kazakhstan, but this is not enough for the long-term development of these technologies. The development of telecommunication technologies is hampered by the following factors: digital inequality of regions in the use of ICT, problems in organizing broadband access, low access speed, high cost of services, in the ICT sector inaccessible to socially vulnerable groups of the population, and others [134–135].

Within the framework of the second direction «Transition to a digital state», a number of works have been carried out on the automation of public services, digitalization of healthcare, social and labor work, law enforcement system, Smart city, etc. In the third direction «Implementation of the digital Silk Road», work is being carried out to ensure universal access to broadband Internet.

3. Digitization of maps and opening of databases. In 2021, in order to implement the State Program «Digital Kazakhstan», the National Project «Technological breakthrough through digitalization, science and innovation», work began on the creation of the National Spatial Data Infrastructure (NSDI).

As part of the NSDI, state geodetic, leveling, and gravimetric networks will be modernized and a unified state coordinate system QTRS (Qazaqstan Terrestrial Reference System) will be installed to replace the 1942 coordinate system, and a unified digital cartographic framework for open use will be created. The implementation period of the NSDI is 2021–2024.

According to cartographic support. To date, digital topographic maps at a scale of 1:25,000 have been created and updated. In total, 65% of the territory of the Republic of Kazakhstan has been digitized and updated.

4.Space technologies. To develop space communications, MDDIAI is currently working to introduce 5G technology in the country. The launch of 5G networks in Kazakhstan is planned by the end of 2022 in cities of republican significance, and in 2023–2025 in regional centers.

The data transfer rate will be at least 70% of the maximum value provided for in the subscriber's tariff plan.

In the period from 2021 to 2023, JSC «NCSRT» is implementing a program aimed at researching possible ways to create a domestic ultra-light launch vehicle (Ultralight launch vehicle) for space purposes. As part of this study for 2022, the following were developed:

- software for internal ballistics of a solid propellant rocket engine (solid propellant rocket engine), intended for the design of the ULV engine;
- a prototype of solid rocket fuel that will be used in the ULV project;
- technology for the production of domestic carbon fiber prepregs intended for aerospace technology, incl. for ULV;
- Software for calculating the program flight path of the launch vehicle, intended for calculating the trajectory of the ULV launch vehicle.

Development of the space industry - prospects and plans. In 2022, the industry's space systems operated normally, and the assigned tasks were generally completed. The constellation of domestic satellites consists of 5 spacecraft for remote sensing of the Earth and communications.

For communication satellites, a set of works was carried out on a technical audit and extension of the resources of the KazSat-2 communication spacecraft for two years - until December 2026. Similarly, the resources of the remote sensing satellites «KazEOSat-1» and «KazEOSat-2» have been extended for two years – until the end of 2023.

Using the capabilities of remote sensing spacecraft, government agencies today carry out space monitoring to solve more than 40 problems. The Baikonur Cosmodrome operates under lease as normal, and within the framework of the contractual obligations of JSC Baiterek JV, a project is being implemented to create the Baiterek space rocket complex, the implementation period is until the end of 2023.

To address issues of ensuring digital security, the «Cyber Shield of Kazakhstan» Cybersecurity Concept is currently being implemented, within the framework of which a set of measures has been carried out on cybersecurity and personal data protection, which has had a positive impact in the UN Global Cybersecurity Ranking, where Kazakhstan has moved from 40th to 31st place.

Space industry in Kazakhstan Thanks to launches from the Baikonur cosmodrome, the International Space Station (ISS) operation is ensured.

Within the framework of the Republican budget program «Applied Scientific Research in the field of space activities» for 2021–2023, four targeted scientific and technical programs are being implemented.

Leading companies in the world are actively developing the creation of 6 G networks, therefore in Kazakhstan it is necessary to create technological prerequisites for the implementation of 6 G network, for this the Ministry of

Digital Development, Innovation and Aerospace Industry needs to pay sufficient attention to this [134–138].

2. *Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations*

1. Information technology. MDDIAI discussed with Eutelsat-One Web, ReOrbit and SES various strategies and technological solutions to ensure equal access to digital opportunities to provide connectivity to remote communities and provide Internet access to hard-to-reach locations using low-orbit satellite constellations provided by these companies [139] .

2. Telecommunications and digital technologies. Currently, telecommunications and information technologies are rapidly strengthening their positions in the aerospace industry, and systems based on neural networks and artificial intelligence, ultra-high-bandwidth communication systems, and new optical technologies are also being developed. It is obvious that as a result of digitalization, a whole block of new technologies has appeared, which is actively developing in the space industry [140].

Over the past 8 years, a group of scientists from the Institute of Electronics and Electrical Engineers (IEEE) has compiled a list of the top technology trends.

1. 3D integrated circuits. 3D IC is a three-dimensional integrated circuit (IC) built by vertically combining different chips into one package. Combining crystals into one package instead of several packages on a printed circuit board increases the density of input - output information by 100 times. And thanks to the latest technologies, the energy transfer per bit is reduced by up to 30 times [141].

2) Universal NRAM memory from Nantero. The so-called «universal memory» is a next-generation memory system that has a super-dense structure and can replace literally everything - from flash memory in digital cameras to hard drives of any type [142].

5) BigData. With the help of BigData technology, many problems are solved, for example, previously unprecedented volumes of information coming from different sources require the creation of innovative solutions for the effective analysis of such amounts of data. Research shows that using AI + BigData can automate almost 80% of all physical work, 70% of data processing work and 64% of data collection tasks. Using natural language processing, AI can distinguish between types of information and find possible connections between data sets [143].

6) SQL and NoSQL. NoSQL information database. NoSQL technology has replaced SQL relational databases. The technology is designed to reduce workloads and reduce the cost of implementing BigData systems. With NoSQL, companies can gain greater flexibility in storing, retrieving, and processing large volumes of diverse data in real time [144].

7) Cloud technologies. Currently, cloud technologies are increasing their presence in various areas, and more and more companies are using them in a variety of IT segments. By the end of 2023, the global cloud computing market will reach a capitalization of $ 700 billion. By 2025, enterprises will deploy up to 95% of new workflows on cloud platforms. These statistics clearly show that cloud technologies will play a key role in IT in the coming years [145].

9) AI-powered cybersecurity. The annual increase in the number of cyber attacks and their severity is forcing cybersecurity companies to look for technical solutions to eliminate vulnerabilities. Artificial intelligence can detect malware with a high degree of accuracy due to the availability of large amounts of data for deep learning models [146].

3. Space technologies. At KazNU named after. Al-Farabi, since 2010, a project has been underway to form a scientific and innovative basis for the domestic school of space technology. For the first time, Kazakhstan acted as the lead developer of space systems. Conditions have been successfully created in the form of modern infrastructure (a cluster of space technology and technologies based on Al-Farabi Kazakh National University, which includes a laboratory for developing nanosatellites and an international remote sensing center) [147].

Kazakhstan will produce communications satellites jointly with the French Airbus Defense and Space. The prospects for joint projects in the field of creating communication satellites to replace KazSat satellites and remote sensing satellites that are ending their service life were discussed with the Thales Alenia Space company, and with Airbus Defense and Space - the development of an assembly and testing complex (ATC) and the production of satellites. As a result, Kazakhstan plans to produce communication satellites together with French specialists; the first device assembled in Kazakhstan is planned for launch in 2026 [148].

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

1. Information technology. A number of research projects aimed at solving problems of information and communication technologies have been carried out at the Institute of Information and Computing Technologies of the Republic of Kazakhstan [149].

Kazakh scientists have invented an innovative approach that can change the global IT industry - they have developed polynomial algorithms for solving NP-complete problems. These solutions will lead to serious optimization of the world's information systems. Idemia is implementing a project in Kazakhstan to implement an information system for collecting data about air passengers (APCAS) through the joint venture Qazaqstan Identity & Security (QIS). The system is currently in trial operation [150].

Scientific research has been carried out in the field of predicting the reliability of linear wireless sensor networks with the potential for using the Internet of Things in Kazakhstan. The results of using unmanned aerial vehicles to solve engineering and geodetic problems in maintaining the state urban planning cadastre are presented [151].

In 2022, NSCRT carried out research work under the Republican budget program 008 «Applied scientific research in the field of space activities» with continuation for 2023–2025 under grant funding projects of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan [152].

2. Telecommunication technologies. The following projects based on these technologies can be noted:

A. Grant funding projects of the Ministry of Education and Science of the Republic of Kazakhstan for 2021–2023, 2022–2024 have been completed and are being implemented. [153].

1 . «Development of domestic technology for producing a radio-transparent high-strength composite for the bodies of military unmanned aerial vehicles and aerospace equipment»;

2. «Technology for remote assessment of the state of vegetation in Central and Northern Kazakhstan under drought conditions, taking into account natural and climatic features based on long-term satellite information».

B. The following business contracts have been completed:

1. Research work «Creation of a system for space and ground-based monitoring of water-supplied territories that are promising for the development of irrigated agriculture in the southern region of the Republic of Kazakhstan».

A database of irrigated territories and lands that are promising for irrigated agriculture in the southern region of the Republic of Kazakhstan has been created. Mapping of selected promising areas for irrigation was carried out based on space and ground monitoring in the Kyzylorda and Turkestan regions.

2. Consulting services were provided on space industry technologies within the framework of the scientific project «Development of an expert decision support system in the space industry».

3. Space technologies. The development of global competition in the field of space activities, modern development trends require new innovative solutions: digitalization of industry; creation of new materials; artificial intelligence technologies; robotization of production [154].

To achieve an advantage, leading competing countries in their strategic planning documents in the field of technology (European Space Agency Roadmap, NASA Technology Taxonomy) established fundamental directions for the development of rocket and space technology production technologies : additive manufacturing (additive technologies); the use of new materials, including non-metals; virtual and augmented reality (VR/AR); progressive maintenance of industrial equipment; artificial intelligence; robotics and sensors; development of digital twins of products and production systems; virtual tests; development and improvement of traditional machine-building technologies.

The use of additive technologies for the manufacture of promising load-bearing shell structures for tanks of the STC launch vehicle stages from polymer structural materials (PSM) will reduce the weight of the structure by 20–35%; manufacturing complexity – 1.5–3 times; energy intensity of production – up to 8 times; the time required to create a structure is 4–5 times [155]. International experience in the application of additive technologies in the aerospace industry: a) startup company Launcher - liquid-propellant rocket engine; b) SpaceX SuperDraco engine.

It is important to emphasize that the effectiveness of using additive technologies is objectively interconnected with the level of development of digital production. Digitalization of production based on additive technologies provides corresponding advantages in terms of time, costs and indicators of design manufacturability of rocket and space technology products [155].

It should be noted that there is widespread and intensive development of methods for progressive maintenance of industrial equipment based on the actual condition determined by the results of vibration diagnostics, as well as using the IETM (integrated electronic technical manual) and remote AR assistants [156]. At the same time, modern trends in the development of digital production determine the possibility, and the strategic goals of the development of space exploration, determine the need to use additive manufacturing in outer space.

Today, there are examples of successful implementation of software solutions with AR elements at the world's leading aerospace companies (Boeing and Lockheed Martin). According to a Boeing report, the use of AR technology when laying and connecting cables in on-board systems of aircraft made it possible to reduce the operation time by 20% and reduce the number of errors by approximately half . The development of industrial technologies leads to a significant increase in the volume and complexity of information on developed design and technological solutions (DTS), so their effective use is impossible without the parallel development of intelligent technologies.

The objective complication of DTS, coupled with tightening requirements for the production time of rocket and space technology (RST) products, requires the widespread introduction of robotics and sensors to increase the efficiency of manufacturing particularly complex products.

It must be especially emphasized that the above areas of technology development are implemented on the basis of the concept of complete digitalization of processes (product life cycle) of RST. Digital design and modeling, product management at all stages of the life cycle, the so-called Smart Design are based on « smart production» - Smart Manufacturing. This concept is being implemented by the US Department of Defense Advanced Research Projects Agency DARPA.

The PTC (USA) company, which develops industrial software, is working to create a digital twin of a physical product both for the organization and for the maintenance and support of the product [157].

Priority V – «Scientific research in the field of natural sciences»

Basic research in geography

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

Geographical science of Kazakhstan, in accordance with the «Strategy – 2050», identifies as the main directions: assessment, forecast and management of water resources; rational use of the country's natural resource potential; landscape-ecological support for socio-economic development; development of the recreation and tourism industry; dangerous natural phenomena and natural disasters; atlas mapping.

A breakthrough in the field of forecasting and early warning of natural disasters can be achieved by developing the fundamental principles, methods and technologies for analyzing large amounts of ground-based and satellite geological-geophysical, geographic and geodetic data using system analysis, mathematical modeling, digital mapping, machine learning and AI. In [158], the interrelations between elementary circulation and blocking processes on the atmosphere of cities are demonstrated for the first time; examples of the use of various methods of analysis, modeling and mapping of natural hazards are presented in [159–161].

A generally recognized trend in modern geography is recreational geography and prospects for the development of tourism; examples of its implementation in Kazakhstan are given in [162–164]. The activation of the tourism industry increases interest in the historical-geographical and historical - ethnographic topics of work. On this topic in the Web of Science database for 2020–2022. 6 papers were presented [165–170]. Article [171] demonstrates the role of geographic factors in determining geopolitical risks in assessing cross-border investments and international stability initiatives.

Institute of Geography and Water Security (hereinafter referred to as IGWS): main achievements for 2022

*Solving water problems***.** IGWS publications reflect ways to solve problems of assessing water quality, the impact of climate change and anthropogenic factors on both river flow, and the use of new research technologies: Internet of Things technologies, AAS measurements of atmospheric deposition of copper and lead in snow cover, analysis of the state of dammed glacial lakes moraine dams, and threats from glacial debris flows [172–182].

The field of hazardous natural processes is of particular importance for Kazakhstan**.** The IGWS has developed a method for assessing the level of avalanche danger, trained an AI computer program to recognize avalanche situations of different levels in Ile Alatau using the StatSoft neurosimulator, and publishes an Avalanche Bulletin weekly. In [183–184], the results of geodetic measurements of the mass balance of some glaciers of the Trans-Ili Alatau and the methodology for using mathematical statistics to assess the level of avalanche danger are presented.

In 2022, according to *the assessment of natural resource potential* developments of landscape-agroecological zoning of the Turkestan region are presented; assessment of recreational capacity and priority ways for sustainable development of tourism, taking into account the determination of norms for recreational loads; approaches to integrated land use planning at the landscape level have been introduced. Based on GIS, a historical and ethnographic map of the

Central Asian countries was created; to art of rare species of flora and plant communities [185–190].

In the field of *geography of tourism and recreation*, a new paradigm for the development of tourism in the Republic of Kazakhstan has been created, taking into account the recreational needs of the population while maintaining the quality and sustainability of the natural subsystem based on the development of theoretical, methodological and applied support for the development of the national tourism industry [191–195].

In recent years, the Institute's employees have received 10 copyright certificates and 6 implementation certificates. Author's certificates reflect the results of important stages in the implementation of fundamental and applied program research of the IGWS. Acts of implementation demonstrate the high relevance and importance of the results of the work of the IGWS at different levels of their use. Thus, the methodology for short-term background forecasting of mudflow events of storm genesis in the Ile Alatau river basins is successfully used in the operational practice of the RSE «Kazhydromet»; The assessment of pollution with polychlorinated biphenyls in aquatic ecosystems of large transboundary basins was used by Kazakh Research Institute of Fishery in developing a set of measures for the protection and integrated use of water and biological resources.

IGWS research plays a decisive role in solving transboundary problems of water allocation: the GIS «Water Resources of Kazakhstan and Their Use» was used by the Ministry of Agriculture of the Republic of Kazakhstan during the negotiation process of the Kazakh - Chinese Joint Commission, as a result, the principles of the priority of preserving the regenerative properties and environment-forming functions of water resource systems in transboundary basins were developed. The results of compliance with these principles are reflected in the acts of implementation and development of scientific and applied foundations for sustainable water supply to the population for the period until 2050 for use by the MENR of the Republic of Kazakhstan in negotiations with China.

KazNU named after. Al-Farabi, Faculty of Geography and Environmental Management (hereinafter referred to as FGEM): main achievements for 2022

The main results of FGEP research on scientific projects in 2022 were published in monographs and scientific articles by department staff, including conferences and journals indexed in the Scopus database [196–201]. 10 documents of protection and 6 acts of implementation were received in such areas as «Tourism», «Climate change», «Manifestation of national traditions in modern times». When implementing tourism projects, both classical environmental and economic models were used, as well as the development of a new approach to studying the relationships between geographical, environmental and economic parameters based on the substantive interpretation of the results of the method of multivariate statistics of component analysis for constructing target environmental functions and a cognitive model for determining residual recreational capacity. In tourism, 6 certificates were received for copyright objects, reflecting the influence of the specifics of the territorial organization and the development of types of ecotourism on the sustainable development of national parks, the involvement of the local population in the organization of tourism, manifestations of overtourism, and the development of the «NationalParksKZ» mobile application. Confirmation of the relevance of the project results are 4 implementation acts from 3 national parks and the Tourist Information Center of Almaty.

Direction on assessing climate risks of desertification and land degradation presented by two projects of the initial stage of implementation in 2022. Here, 1 certificate was received for material for the development of criteria for recognizing remote sensing data when using them in GIS.

In the sphere of socio-economic research, which is poorly studied from geographical positions, 3 certificates and 2 acts of implementation were obtained for various aspects of analysis, modeling and forecasts of changes in the quality of life and health of the population during the introduction of digital technologies in the Republic of Kazakhstan.

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

Experts from the National Research University «Higher school of economics» and the Ministry of Economic Development of the Russian Federation on March 23, 2022 presented 10 areas that determine the development of high technologies in the world: Artificial intelligence (AI); Internet of Things (IoT); 5G technologies; Quantum Computing (QC); Quantum communications (QC); Distributed ledger technologies (DLT); Electricity transmission and distributed energy systems (EDS); Electricity storage systems (ESS); New materials and substances (NMS); Advanced space systems (PSS).

In geographical research, AI and IoT are already used; 5G will come with a change in computer equipment, followed by QC, QC, and DLT, which ensure the modernization of the processes of calculation, protection and data transmission. EDS and ESS are useful for increasing the efficiency of field geographical research, NMT will manifest itself in updated measuring instruments and computers. PSS will improve the quality of TV.

About risks: The key factors for the CIS are the high dependence on imports of components and equipment necessary for research and development, and the lack of qualified specialists to work with innovative solutions.

IGWS participated in the development of more than 20 international projects together with scientists from Germany, France, Switzerland, Sweden, Finland, Italy, Japan, and China. By agreement between the Government of the Republic of Kazakhstan and UNESCO, the Central Asian Regional Glaciological Center was created on the basis of the Institute under the auspices of UNESCO, as well as the International Water Assessment Center (IWAC) as a regional structure of the OSCE. Created within the framework of the international program of the European Community «Caspian sea environmental and industrial data&information service (Caspinfo)», metadata and maps on natural conditions, resource potential of the

Caspian Sea and its coastal part were included in the world database on the study and use of resources of the oceans and seas. As a result of the project, Google Maps Demonstrator and the CASPINFO Portal were developed and implemented. The CARAWAN project was completed in 2020 Central Asia Research and Adaptation Water Network: «Central Asian research and adaptation of the water network: characteristics and forecast of water availability and quality, natural hazards in glacier feeding basins». Performers: University of Reading, (Reading, United Kingdom); JSC Institute of Geography and Water Security (Almaty); Central Asian Institute of Applied Geosciences (Bishkek); Institute of Water Problems, Hydropower and Ecology (Dushanbe).

Under a UNDP grant in 2020–2021, the project « Development» was carried out of zoning schemes and landscape planning for sustainable management of key biodiversity zones in 7 pilot districts of Almaty region («Services for the development of zoning and landscape planning schemes for the sustainable management of key biodiversity zones in 7 pilot districts of the Almaty region»), KazNU named after. Al-Farabi.

In 2021-2022, KazNU named after. Al-Farabi together with the IGWS carried out a project of the « Research England» Foundation. «Coping with difficult times: increasing preparedness and reducing vulnerability to debris flows in Central Asia». University of Reading (UK), Central Asian Regional Glaciological Center under the auspices of UNESCO (Kazakhstan), Institute of Geology and Geophysics named after. Abdullaev, Uzhydromet (Uzbekistan). In 2021–2024 implement the European Union program ERASMUS: New courses on Geospatial engineering for adaptation of coastal ecosystems to climate change.

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries.

There are 3 scientific schools in the IGWS:

1) Scientific school of water problems and glaciology – fundamental and applied research in the field of formation, use and protection of surface water resources of the Republic of Kazakhstan. Year-round monitoring of the cryosphere in the Northern Tien Shan is carried out at a glaciological station (Tuyyksu Glacier), hydrophysical (Big Almaty Lake) and geocryological (Zhusaly-Kezen pass). New catalogs of glaciers in the river basin have been compiled. Karadarya and Tien Shan basins.

2) Scientific school of landscape science and geoecology – training of scientific personnel of PhD doctors; development of methods for landscape research of arid natural systems under international programs (UNESCO, GEF, UNDP) and individual grants - McCarthur Foundation (USA). Assessment methods, criteria and indicators for the development of natural agricultural systems have been refined and developed.

3) The scientific school of the laboratory of geotourism, geomorphology and natural hazards is today the only scientific unit in Kazakhstan dealing with fundamental problems of relief formation, anthropogenic transformation and the risk of developing hazardous processes.

At the FGEM of KazNU named after. Al-Farabi there are 4 scientific centers (schools):

1) *Center for Geographical Research and Additional Professional Education* - current problems of geography, GIS and geoinformatics: development of a system of measures to prevent pollution of the river valley. Ilek, Aktobe reservoir and underlying areas with forest; an environmental database was created based on the results of field research for radioecological monitoring of the territory of the former STS; new values of maximum flow rates in the river basin Yesil for risk assessment during catastrophic floods.

2) *Center for Digital Cartography and Applied Geodesy* - processing and analysis of information in digital cartography, engineering and geodetic surveys: a comprehensive solution to geo-ecological problems of the border Kazakh-Kyrgyz sector based on a landscape-ecological approach, a series of thematic medium-scale assessment maps for balanced transboundary environmental management and a map of address environmental activities.

3) *COMSATS Center for Climate and Sustainability* – assessing the impact of environmental and climatic variability on economic development; encouraging regional and global partnerships: the flow characteristics of the main rivers in the region were calculated, the impact of economic activities on river flow through channel regulation was assessed; The «Degree-Day» method was tested to determine the amount of water loss from the snow cover.

4) *Center for Problems of Recreation and Tourism* – assessment work on the tourism and recreational potential and capacity of territories; modernization of digital tourism content: the model for the development of ecological tourism in Kazakhstan has been optimized, ensuring its sustainable, balanced, safe and effective development, a unique map of the potential for the development of ecotourism in rural areas has been created, the theoretical foundations of effective methods of bank protection have been substantiated in order to stabilize the coastal abrasion-denudation ledge and development recreational potential of Lake Alakol.

Fundamental and applied research in mathematics

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

An analysis of the current state of mathematical science in the country was carried out based on scientific research materials of Kazakhstani mathematicians published in 2020–2022 in the form of articles or reviews (Review Article or Article) in journals indexed by the Web of Science Core Collection. Only publications in journals with a WoS impact factor, that is, from the Science Citation Index Expanded, were considered.

The share among such publications of articles and reviews in the field of research «Mathematics» in the world for 2018–2022 is 3.5%, among publications of authors with Kazakhstan affiliation – 7.3%, which is 2.1 times higher than the world average. According to this indicator, Kazakhstan's mathematical science is in first place, beating such areas of research as «Physics» and «Energy Fuels» with coefficients of 2.0 and 1.8, respectively (fig. 3.42).

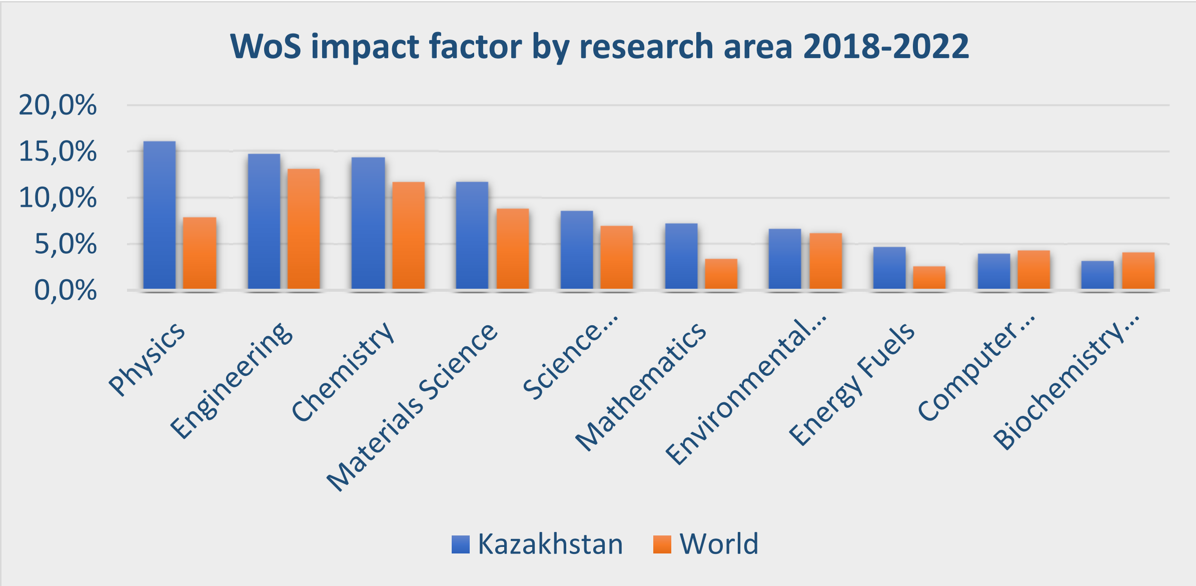


Figure 3.42. Share of articles with WoS impact factor by research area

A total of 704 such articles or reviews were published in 2018–2022 with the following distribution by year: 2018–121, 2019–119, 2020–140, 2021–163, 2022 – 161.

Almost 40% of such articles by Kazakh mathematicians were published by employees of the Institute of Mathematics and Mathematical Modeling. Almost 27% are accounted for by Nazarbayev University and KazNU named after Al-Farabi.

A significant part of such articles was published based on the results of joint scientific research with foreign scientists. The largest number of joint articles was published with scientists from Ghent University, Belgium (73 articles or 10.6%); Russian Academy of Sciences, RF (65 or 9.5%); Queen Mary University London, London, UK (43 or 6.3%); University of London , London, UK (43 or 6.3%); Peoples Friendship University of Russia, Moscow, Russian Federation (38 or 5.6%); Sobolev Institute of Mathematics, Novosibirsk, Russian Federation (26 or 3.8%); Imperial college London, London, UK (24 or 3.5%); Near East University, Nicosia, Republic of Cyprus (20 or 2.9%); Lomonosov Moscow State University, Moscow, Russian Federation (18 or 2.6%) (fig. 3.43).

In 2022, Suragan had the largest number of published articles in journals with the WoS impact factor Durvudkhan (14 articles) and Kashkynbayev Ardak (8) from Nazarbayev University, Torebek Berikbol (6) and Kassymov Aidyn (5) from IMMM, Kalybay Aigerim (5) from KIMEP. Moreover, they are all young scientists.

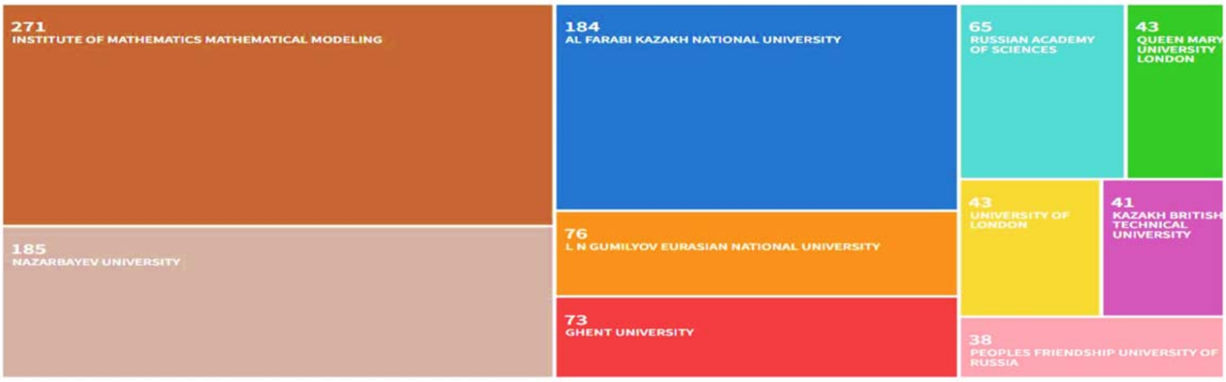


Figure 3.43. Number of articles based on the results of collaborative research.

As is known, in Kazakhstan one of the traditionally actively and successfully developing areas of mathematical science is the theory of differential equations and its applications to problems of mathematical modeling.

Kazakh mathematicians have studied various linear and nonlinear mathematical models described by differential and differential-functional equations. These studies cover a wide range of mathematical models and equations with different properties. They represent various aspects of mathematical modeling and analysis of differential equations carried out by different research groups at different universities and research centers.

These studies consider various types of differential equations with fractional derivatives, integro-differential equations, as well as subdiffusion and biharmonic type equations. Scientists have investigated various aspects of these equations, such as the existence and uniqueness of solutions, stability, analytical properties, and asymptotic behavior. Various boundary conditions, including Dirichlet and Neumann conditions, are also investigated.

The research also includes the analysis of various mathematical models such as heat diffusion in wire models, wave equation and beam models, and Laplace equation models. The correctness of these models is considered and their properties, such as preservation of analyticity and behavior at infinity, are analyzed.

In addition, some studies consider inverse problems, such as the problem of finding coefficients or sources in equations. Also, some works study composition operators and their properties in various function spaces. All of these studies contribute to both the development of mathematical theory and its applications, especially in the fields of mathematical physics, control theory and scientific computing.

Significant achievements have been obtained in the field of stochastic equations, inverse problems of dynamics, differential equations with parameters, integro-differential equations and various boundary value problems. Scientists have conducted research in the field of problem solvability, stability of solutions, various solution methods, numerical algorithms and approximate methods.

Research results include the development of new methods for solving stochastic inverse problems, including the separation and parameterization method. The questions of solvability and stability of solutions of differential equations with parameters and Fredholm integro-differential equations have been studied. Methods have been developed for solving nonlinear boundary value problems and control problems for systems of differential equations with parameters. The connection between periodic problems for systems of differential equations and problems for systems of ordinary differential equations with delay has been studied.

Research has also examined various classes of functions, including unpredictable and Poisson stable functions, and developed methods for solving boundary value problems using averaging and discretization. New analytical results were obtained on the existence of periodic solutions and solutions to various equations.

These studies have important implications for various fields of science and technology, including physics, engineering, finance and biology. The research results can be applied to the analysis and modeling of various dynamic systems, optimal control, risk assessment and the development of new methods of numerical analysis.

Significant achievements have been obtained in the field of mathematical modeling and the study of various equations describing the dynamics of physical systems. Scientists have conducted research in the field of biquaternion wave equations, modeling the dynamics of buildings and structures in the earthquake zone, surface waves of inviscid incompressible fluids, fractional order epidemics, complex modified Korteweg-de Vries equations, Schrödinger-Airy equations and boundary value problems for the Poisson equation.

As a result of the research, new mathematical models were obtained that describe the dynamics of these systems, and their properties were studied. Methods for solving the corresponding equations and numerical algorithms for approximating solutions were developed. The studies included both analytical and numerical approaches.

These studies have important implications for various fields of science and technology, including physics, engineering, geology, biology and medicine. The research results can be used for more accurate modeling and prediction of the behavior of physical systems, the development of monitoring and control methods, as well as for studying the basic patterns and interactions in various systems.

Research carried out by mathematicians at various universities and research centers covers a wide range of problems and issues in the field of mathematical analysis, function theory, functional analysis and their applications. The research results have important theoretical and practical significance and can be applied in various fields of science and technology.

In particular, issues of nonparametric estimation of the distribution function based on random sampling were studied, which may have application in economics, finance and biomedicine. Research has also been carried out in the field of function theory, including harmonic analysis, approximation theory and operator theory. These studies included the development of new interpolation theorems, the analysis of spectral problems and estimates for various operators, and the study of the properties of function spaces and high-order differential equations.

An important achievement is also the development of new methods for solving the problem of optimal cubature formulas for function spaces and the study of the properties of pseudo-differential operators with various symbols.

These studies demonstrate the active work of Kazakhstani scientists in the field of mathematics and their contribution to the development of mathematical science and its applications. Further research in these areas may lead to new theoretical results and practical applications in various scientific and engineering fields.

Research in the field of non-commutative functional analysis has been carried out in Kazakhstan for more than ten years. These studies examined various aspects of noncommutative functional analysis. Conditional expectations on non-commutative spaces associated with semi-finite sub-diagonal algebras were investigated. The compressibility of conditional expectation on these spaces was proven. The noncommutative maximal Hardy–Littlewood operator on symmetric spaces of tau measurable operators and noncommutative weak Orlich–Hardy spaces were also studied. Results were obtained related to the extreme points of the set of elements dominated by a given integrable function, and a complete solution to the problem posed by WAJ Luxtmburg in 1967 was found.

Other studies include the construction of submajorization inequalities for matrices of tau-measurable operators, Young-type inequalities for measurable operators, complex interpolation of noncommutative Hardy spaces associated with semifinite von Neumann algebras, and interpolation and the John–Nirenberg inequality on symmetric spaces of noncommutative martingales. Research has also been carried out in the field of singular integrals and corresponding equations, and problems related to the operator singular integral equation with a Carleman shift in Besov spaces and the heat equation with a fractional time derivative have been solved.

Research in noncommutative functional analysis is ongoing, and further results may be important for the development of this area of mathematics and its applications.

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

Some general trends that have been most relevant over the past three years:

● Machine learning and artificial intelligence: The interaction between mathematics and machine learning is becoming increasingly closer. Mathematical methods play an important role in the development of machine learning algorithms such as neural networks, deep learning methods and recommender systems.

● Cryptography and Cybersecurity: With the development of the digital economy and the widespread use of the Internet, the importance of cryptography and cybersecurity has increased. Mathematical methods such as number theory and algebra are used to develop cryptographic algorithms and protocols to protect data and information. The use of continuous mathematics methods (for example, differential equations) in cryptography and cybersecurity is one of the new trends.

● Big Data and Statistics: With the constant increase in data volumes, statistics become important for analysis, interpretation and decision making. Mathematical methods and statistical models help identify patterns in large amounts of data.

● Probability theory and financial markets: Mathematical methods such as probability theory and stochastic analysis are widely used in financial mathematics to model and analyze financial markets, option pricing, and risk management.

● Geometry and topology: These areas of mathematics play an important role in a variety of scientific and engineering applications, including computer graphics, medical image analysis, molecular modeling, and topological data analysis.

Analysis of global trends in mathematics should be based on the most current information and research conducted by experts in the field. In this regard, it is necessary to organize separate large studies specifically to analyze current trends in the development of world mathematical science.

Cooperation between domestic mathematicians and foreign scientists is an important aspect of the development of mathematical science and the exchange of knowledge on a global scale. This helps broaden the horizons of researchers, improve the quality of research, increase the level of scientific output and establish close ties between scientific communities of different countries. This also helps to improve the status of Kazakhstani mathematics in the global scientific community and draw attention to the importance of mathematical research in general. Such cooperation occurs at various levels, the main ones being:

1. Scientific seminars and conferences are held in different countries, and mathematicians from all over the world participate in these events, present their research, exchange ideas and find potential partners for future cooperation.

2. Joint publications of mathematicians from different countries. Such publications are the fruits of joint scientific research. They help spread knowledge and promote the development of mathematics.

Kazakh mathematicians most actively publish the results of their research (according to the Science Citation Index Expanded Web of Science database for 2018–2022) together with colleagues from Russia (25%), Belgium (11%), Great Britain (10%), Turkey (7 %), USA (6%), China (5%), Spain (3%).

3. Analysis of achievements and development trends of leading scientific schools in Kazak Analysis hstan and highly developed foreign countries

In Kazakhstan, research in the field of algebra and mathematical logic is actively carried out at the IMMM, ENU named after. L.N. Gumilyov, KBTU, SDU, Nazarbayev University and KazNU named after Al-Farabi, where leading schools in mathematics are concentrated.

In the field of algebra, researchers have studied various properties of algebras, such as embeddability of subalgebras, dimension, cohomology characteristics, identities, finite generation, generating groups of automorphisms, enveloping algebras, commutators and anticommutators, deformations of Schur polynomials and dual Grothendieck polynomials, classification of algebras and other properties. Lie algebras, Leibniz algebras, Sinbeil algebras, Novikov algebras, Poisson algebras and other classes of algebras were studied. Results were obtained in the field of restricted cohomology of Lie algebras, embeddings of metabelian Lie algebras, binary Leibniz algebras, Sinbeil algebras, Novikov algebras and other classes of algebras.

In mathematical logic, researchers have focused on model theory and computability theory. In the field of model theory, complete theories, classes of complete theories from the point of view of describing formulas, the algebra of binary formulas, the number of countable models (Vaught's Conjecture), the algebra of formulaic sets, extensions of theories using types and other properties were studied. Countably categorical weakly o-minimal theories, orderly stable theories, complete lattice theories, and other classes of theories were studied.

In the field of computability theory, various aspects of the Rogers semilattice of recursively enumerable sets, the connection of the standard hierarchy of sets with the Ershov hierarchy, degrees of the hierarchy and other properties were studied. Research has also been carried out on models of complete theories equipped with computable predicates and functions.

Research in algebra and mathematical logic continues, and new results may have important implications for the development of these fields and their applications.

Among the works of young Kazakh mathematicians, noteworthy is the article [202] Medet Nursultanov «Spectral theory for Sturm - Liouville operators with measure potentials through Otelbaev's function» (J. Math. Phys. 2022, 63, 012101), completed by him at the University of Sydney (NSW, Australia) with Robert Fulsche , in which (based on the famous function of M. Otelbaev) the spectral properties of Sturm - Liouville operators with measurable potentials were studied. Two-sided estimates for the spectral distribution function of eigenvalues are obtained. As a consequence, a criterion for the discreteness of the spectrum and a criterion for the membership of resolvents in Schatten classes are derived.

The best works of 2022 are a series of 5 works by the young Kazakh mathematician Kassymov Aidyn from IMMM, published in the journals [203] Bulletin of the Malaysian Mathematical Sciences Society (Q1), [204] Potential Analysis (Q2), [205] Forum Mathematicum (Q3), [206] Publicationes Mathematicae-Debrecen (Q3), [207] Quaestiones Mathematicae (Q3) co-authored with Suragan Durvudkhan, Kashkynbayev Ardak, Ruzhansky Michael, Tokmagambetov Niyaz and Torebek Berikbol. In these works, the fractional Gagliardo-Nirenberg inequality on homogeneous Lie groups was proved and the weighted fractional Caffarelli-Kohn-Nirenberg inequality and a Lyapunov-type inequality for the Riesz potential on homogeneous Lie groups were established (moreover, this inequality is new already in the classical formulation of RN). The inverse Stein - Weiss inequality on general homogeneous Lie groups is proved, which extends previously known inequalities. Using the Poincaré and Folland-

Stein inequalities and Green's identities for the sublaplacian on stratified Lie groups, results on finite-time destruction for viscoelastic wave equations with both strong and weak damping terms on stratified Lie groups are proved. A result was obtained without destruction in finite time for sub-Laplacian heat equations with logarithmic nonlinearity on stratified groups. The existence of local soft solutions of the Cauchy problems for a polynomial equation and a time-fractional diffusion system is proved, and critical exponents of Fujita type and Escobedo-Herrero type are obtained for a polynomial equation and a time-fractional diffusion system, respectively.

Priority VI – «Science of life and health»

Section «Innovative research in medicine and public health»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

The achievements of Kazakhstani science include the works of domestic scientists, noted in accordance with the Decree of the President of the Republic of Kazakhstan dated December 6, 2021

№ 709 State Prize of the Republic of Kazakhstan in the field of science and technology named after. Al-Farabi for outstanding results in the field of development of vaccines and medicines: 1) for a series of works on the topic «Ensuring the biological safety of the Republic of Kazakhstan: advanced scientific technologies and production», presented by the RSE at the PVC «Research Institute for Biological Safety Problems», to the team of authors headed by the General Director, Doctor of Biological Sciences, Prof., full member of KazNANS, member. - corr. Russian Academy of Natural Sciences Zakarya K. They have developed several domestic drugs against coronavirus, including the QazVac vaccine (QazCovid-in).

2) for work on the topic Development and organization of production of a new domestic original medicinal product «Roseofungin –AS» , carried out by the team of authors of the Research and Production Center for Microbiology and Virology LLP, headed by the General Director, Doctor of Biological Sciences, Prof. , acad. Sadanov A.K.

In 2020, by Decree of the President of the Republic of Kazakhstan № 460, the State Prize of the Republic of Kazakhstan in the field of science and technology named after. Al-Farabi was awarded to scientists for their work «Development and implementation of innovative cellular technologies in clinical medicine». The prize was awarded to a team of authors headed by A.K. Baigenzhin, Chairman of the Board of JSC National Scientific Medical Center, Ph.D.

Scientific schools in the field of medicine in the Republic of Kazakhstan are currently actively focused on the development of scientific and technical projects (STP) and program targeted financing (PTF). These two areas are priority areas that have attracted significant attention from researchers and medical professionals.

1. STP «National Program for the Introduction of Personalized and Preventive Medicine in the Republic of Kazakhstan» (executor – NJSC «Kazakh National Medical University» named after S.D. Asfendiyarov, 19 co-executing organizations, 2021–2023).

The first task of the STP is aimed at personalized prevention and primary health care. An analysis of social factors affecting the health of the population of Kazakhstan is carried out through an assessment of the prevalence of chronic non-communicable diseases and the contribution of various risk factors. The study covers 20 400 people (1200 in each region), conducts diagnostic procedures and collects data on health factors [208]. The study analyzes antibodies to SARS-CoV-2 to determine the prevalence of immunity to COVID-19 and the factors influencing it. The work of primary health care organizations (PHC) is assessed according to international methodology, as well as their ability to help patients with COVID-19 and other diseases during the epidemic.

To assess the risk to the health of the population of the Republic of Kazakhstan, an analysis of water quality data in 38 cities of the Republic of Kazakhstan was carried out, as well as an assessment of air quality parameters using descriptive methods of statistical analysis to study the state of air masses in 19 cities of the country.

As part of the task in the field of medical genetics, 13 of the most important socio-economic diseases are being studied, including COVID-19. In total, 13 200 DNA samples were studied, as a result of which early presymptomatic diagnosis and individualized selection of drugs taking into account genetic predisposition are being introduced into practical healthcare in the Republic of Kazakhstan.

A pharmacogenetics study identified 150 drugs whose effectiveness and side effects are associated with genetic predisposition. The number of known pharmacogenes for these drugs was assessed based on GWAS data from 2500 Kazakhs. In addition, 1150 mycobacterial cultures were collected from patients with resistant tuberculosis. Clinical and genetic data were analyzed using a personalized approach and methods of DNA fingerprinting of microorganisms to study the resistance of the tuberculosis pathogen to drugs.

As part of the third task, technology for editing the DNA of T-lymphocytes is being developed and implemented to increase their effectiveness in destroying cancer cells in the treatment of acute leukemia in children [209]. For the first time in the Republic of Kazakhstan, confirmation of the activity of CAR-T lymphocytes in vitro and in vivo was obtained. The results of the studies indicate the effectiveness of mesenchymal stem cells, which will make it possible to develop and introduce into clinical practice a cell transplant with high regenerative potential for restorative and replacement therapy of lost functions of organs and systems.

*2. STP «Development of innovative and highly effective technologies aimed at reducing the risk of premature mortality from diseases of the circulatory system, chronic respiratory diseases and diabetes» (*implemented by JSC Scientific Research Institute of Cardiology and Internal Diseases, 2021–2023). Study results for 2021–2022 indicate positive clinical and hemodynamic effects of new treatment regimens for patients with severe chronic heart failure and resynchronization device; the effectiveness of myectomy on a beating heart in patients with hypertrophic cardiomyopathy; economic efficiency of the iFR method for assessing the functional significance of stenosis in atrial fibrillation. Based on the intermediate results, a demo version of an intelligent computer program (artificial intelligence) was created to analyze the results of coronary angiography and select the tactics of therapeutic intervention for coronary heart disease. The influence of both modifiable and non-modifiable risk factors for the development of diabetes during pregnancy has been established. An algorithm has been developed for the prediction and early diagnosis of gestational diabetes mellitus, which will improve maternal and perinatal pregnancy outcomes.

3. STP «Aging and healthy life expectancy» (executor – Nazarbayev University JSC, 2021–2023).

In 2022, research continued to determine the dynamics of reprogramming age-related signs of aging, the role of proteins in neurodegeneration, the creation of genetically modified strains of bacteria that affect the development and progression of cancer; conducting a comprehensive diagnostic study to distribute groups of patients with low/high risk of lymphoma and chronic lymphocytic leukemia based on a comprehensive analysis of lymph node biopsy; identifying factors that regulate the transactivation of endogenous retroviruses after infection with rhinovirus and SARS-Cov-2, which contribute to increased mortality in older people.

4. STP «Development and scientific substantiation of innovative technologies to improve the efficiency of diagnosis, treatment of injuries, consequences of injuries, diseases of the extremities, spine and pelvis» (executor – RSE at the PCV « National Scientific Center of Traumatology and Orthopedics named after N.D. Batpenov» , 2021–2023 year).

Innovative methods for treating chest and spinal deformities have been introduced. Methods for draining pleural cavities have been developed: a plate for correcting carinatum deformity and a device for introducing bone replacement material. Mesenchymal stem cells and autologous fibrin mass were used in 11 patients. Surgeries were performed on 21 patients with pelvic injuries using a modified Stoppa surgical approach using the developed pelvic plate. A technique based on cell technology has been developed to accelerate the healing of fractures and damaged knee joints. A total of 80 patients were recruited for a clinical study of the effectiveness of heparin - conjugated fibrin hydrogel. A minimally invasive method of its implantation has been developed. Thirty patients underwent revision knee arthroplasty using the double cementation technique, which ultimately led to an improvement in functional indicators in these patients.

5. STP «COVID-19: Scientific and technological substantiation of the response system to the spread of new respiratory infections, including coronavirus infection» (executor – NJSC « Medical University of Karaganda», 2021–2023).

Based on data analysis, three COVID-19 spread models were developed, including system dynamics and time series analysis (ARIMA and TBATS). After COVID-19, patients often experienced cardiovascular lesions and type 2 diabetes mellitus. An increase in trimethylamine oxide (TMAO) levels was also observed on days 7–8. In pregnant women who had recovered from COVID - 19, the placenta more often contained intervillous thrombi and fibrinoid deposits, indicating hypercoagulation.

Mortality analysis revealed an increase in maternal deaths from extragenital diseases (76% in 2020) associated with COVID-19. No negative impact on infant mortality was found. An increase in mortality from diseases of the circulatory system was noticed in all age groups, especially over 85 years, among men and the urban population. Analysis of immunity after Sputnik-V vaccination showed the need for dosage adjustment for patients with a history of COVID-19. A decrease in specific antibodies and immunoregulatory molecules, as well as a long-term increase in antiviral cytokines, were detected.

6. Scientific and technological progress «Development and development of innovative technologies for early diagnosis and treatment of malignant diseases, taking into account modern genomics approaches» (executor – Kazakh Research Institute of Oncology and Radiology JSC, 2021–2023).

As part of the program, the population is screened using new medical equipment specifically designed to detect cancer. Programs for early diagnosis of lung cancer (using low-dose computed tomography), stomach cancer (through the introduction of chromoscopy technology), ovarian cancer (based on genetic tumor biomarkers), colorectal cancer (with the introduction of new immunochemical and radiological methods of presymptomatic diagnosis), acute leukemia and extragonadal germ cell tumors in children (based on multimodal technologies of molecular genetic and immunophenotypic diagnostics); vaccination program against human papillomavirus (HPV) and cervical cancer prevention. This will increase the detection rate of malignant diseases at an early stage and personalize the approach to cancer treatment.

7. STP «Development of a program of molecular cytogenetic research and creation of a biobank of tumors of the central nervous system» (executor – JSC «National Center of Neurosurgery» (NCN), 2021–2023).

As part of the project, a biobank is being created with a subsequent digital format. The creation of a biobank is the first and, of its kind, a unique project aimed at collecting a collection of tumors of the central nervous system (CNS) on the basis of JSC NCN, developing new and improving existing methods of high-tech treatment and diagnostics; creation of fundamentally new individual protocols for treatment, prognosis and monitoring of oncological diseases of the central nervous system, streamlining standards for the selection and storage of biospecimens, creation of quality criteria for biospecimens, unification of disparate databases created on the territory of the Republic of Kazakhstan into a single system.

8. STP «Development and scientific substantiation of public health technologies, biological safety for the impact on the prevention of dangerous infectious diseases» (executor – RSE at the PCV «National Scientific Center for Particularly Dangerous Infections named after M. Aikimbaev», 2021–2023).

Based on the results of sequencing plague microbe strains, a method for predicting epizootic activity of plague in natural foci of the Republic of Kazakhstan was developed for the first time. For the first time, the boundaries of the ranges of three species of the main and minor carriers of plague pathogens (great, ruff-legged jerboa, gray marmot) in the territory of the Tien Shan highland and Central Asian natural focus of plague have been clarified. An electronic database on the large, hairy jerboa and gray sura has been compiled and updated. Species of ticks have been identified as potential carriers of the Crimean-Congo hemorrhagic fever virus (CCHF) in the western and southwestern regions of Kazakhstan, which are not endemic for CCHF. The current spatiotemporal status of 22 natural foci of tularemia was determined, nosogeographic maps were created, foci of tularemia with reduced potential were identified (in Akmola, Kostanay, Kyzylorda regions), foci with a high risk of infection were identified (in Almaty, Aktobe, East Kazakhstan and West Kazakhstan areas). Cholera vibrios isolated in Kazakhstan from 1970 to 2020 were studied. Genes indicating their specificity and virulence - ompA, ctxA and tcpA - have been identified, which will be used for rapid diagnosis during outbreaks of infection.

9. STP «Development of new anti-infective drug» (executor – JSC «Scientific Center of Anti-Infective Drugs», 2021–2023).

New original drugs were obtained and the pharmaceutical development of an iodine coordination compound was carried out: KS-206 (IF) - an interferon inducer, KS (PA) and a combination drug, KS (PA) and amoxicillin. New data have been obtained on the pathogenetic mechanisms of chronic infectious and inflammatory bacterial diseases.

Dosage forms of a new anti-infective drug have been developed for the treatment of chronic infectious and inflammatory diseases. The following medicinal substances and finished dosage forms are registered in the Republican Bank of Standard Samples of Medicinal Substances: KS IF (KS-206), KS IM, «FS-1 powder», KS (PA), KS «Efesovir solution for oral administration», «FS- 1 solution for oral administration», tablets «FS - 2 1.9 mg». The new substances are protected by two patents.

16 batches of four substances KS-206 (IF), KS (PA), KS (IM), FS-1, KS-195 were produced under GMP conditions; medicines – FS-1 (2 series), Efesovir (2 series) and FS-2 tablets (5 series).

*10. STP «Study of reversal of antibiotic resistance of pathogenic microorganisms» (*performer – JSC «Scientific Center of Anti-Infective Drugs», 2021–2023).

We isolated, identified and sequenced 6 isolates of microorganisms causing nosocomial infections from clinical samples. The quantitative and qualitative composition of the microbiome and virome of animals after therapy with the coordination compound KS-195 was determined. The acute toxicity of the coordination compound KS-195 after oral and intraperitoneal administration was studied in a mouse model. The compound is low toxic. A laboratory synthesis of two series of the coordination compound KS-195 was carried out - 02231221 and 02050522. The stability of these series was studied for 9 months, and tablets of the coordination compound KS-195 were obtained. Work has been carried out to scale up laboratory technology in pilot production conditions. Three series of coordination compound KS-195 have been developed (02251022, 03251022, 04251022). A technological scheme for pilot industrial production of KS-195 has been developed.

All scientific and technological progress carried out comply with the strict standards of scientific ethics established by the Declaration of Helsinki, which is the fundamental document in the field of medical research ethics.

According to the preliminary results of the scientific and technological progress, 52 scientific articles were published (18 in high-ranking journals, 34 in publications recommended by the CQAFSHE Ministry of Education and Science of the Republic of Kazakhstan), 36 theses and 59 oral presentations at international conferences, 4 patents were received, incl. 1 Eurasian, 43 copyright certificates, 37 acts of implementation.

A detailed analysis of publication activity in the field of medicine is presented in the section «Indicators of research activity of scientists».

In the priority area «Science of Life and Health», the Ministry of Education and Science of the Republic of Kazakhstan financed 21 scientific and technological progress with a implementation period of 2021–2023.

Over the past years, Kazakhstan has been actively developing the pharmaceutical industry and science, striving to become an independent supplier of medicines and develop its own pharmaceutical industry. Important areas of development of pharmaceutical science in Kazakhstan are research and development in the field of new drugs and technologies, the creation of innovative pharmaceutical products to improve public health. The development of pharmaceutical science also includes research into the effectiveness and safety of drugs during clinical trials. Kazakh scientists actively cooperate with international pharmaceutical companies and organizations to exchange knowledge and experience, as well as to attract investment and technical expertise. A detailed analysis of the development of pharmaceutical science and the industry is presented in the «Pharmacy» section of priority 6 «Life and Health Science» of the National Science Report for 2021 [https://nauka–nanrk.kz/assets/Doklad%20ru.pdf, (pp. 98–105)].

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

In recent years, medical science in the field of MedTech (Medical Technology) has witnessed several noteworthy trends shaping the future of healthcare [210]. These trends span a wide range of advances, innovations and changes that are revolutionizing the way healthcare is delivered and improving patient outcomes. In terms of competitiveness compared to other countries, Kazakhstan is at the initial stage of MedTech development and cannot yet compare with leading countries in this field, such as the USA, Canada, Germany and Japan [211]. Below are the main global trends in medical technology and their application in Kazakhstan:

1) *Artificial intelligence (AI) and machine learning (ML)* are used for various purposes such as medical image analysis, predictive analytics, drug discovery, and personalized medicine [212]. AI-powered algorithms can process massive amounts of data quickly and accurately, leading to more accurate diagnoses, treatment recommendations, and improved patient monitoring.

The use of AI in medicine is also beginning in Kazakhstan:

● The Cerebra project was launched in 2021 as part of a project of the Research Institute of Neurorehabilitation in Almaty. Its goal is to create deep learning technology for diagnosing and predicting brain diseases [213].

● AI in the field of prediction and diagnosis of oncology and pneumonia. The software product, created by Almaty-based companies ForUs Data and Crystal Spring, is capable of identifying various pathologies, including pneumonia and signs of coronavirus (COVID-19).

2) *Telemedicine and remote patient monitoring*. Telemedicine has experienced exponential growth, primarily due to the COVID-19 pandemic. At the National Scientific Medical Center in Astana there is a department of telemedicine technologies, which allows to significantly increase the route of cooperation between the center and regional and foreign institutions [214]. The country already has companies and institutions, such as the National Scientific Oncology Center, the iDoctor search service for doctors and medical centers, and Sapa Telemedicine Center LLP, operating in the field of telemedicine.

As of 2022, 2 international projects are being implemented in the field of providing telemedicine services: 1) the «Telemedicine 2022» project - a platform for online consultations, implemented by the Medical Avenue company together with partners from Korea and other countries [215]; 2) the Sezim project – an online platform for psychotherapists to conduct sessions with clients confidentially [216]. In more than 5.8 thousand state healthcare facilities, the IT infrastructure of medical organizations has been developed, medical information systems (MIS) (98.2%), various mobile and web applications (more than 20) have been introduced, and their integration has been carried out. A number of digital services have been implemented for citizens of the country in the patient's personal account on the eGov e-government portal and in the eGovMobile mobile application (Vaccination Passport, etc.) [217].

3) *Robotics and automation* are transforming various aspects of healthcare. As of 2022, in the Republic of Kazakhstan, scientific research and development in this area are at the initial stage in the form of initiative, student/master's or startup projects, without conducting clinical studies and safety trials.

4) *Big Data – big data and analytics*. Analysis of large data sets can reveal valuable insights, patterns, and correlations that can aid in disease prevention, early detection, and treatment optimization [218, 219]. Data analysis is possible on the basis of existing MIS. For example, in Kazakhstan, the national electronic health record was launched in 2018 and allows patients to store their medical data in digital format and access medical services online. Pharmaceutical databases are also an important source of medical data. They contain information about medications, their composition, dosage, side effects and interactions with other drugs. In addition, epidemiologists use big data to track the spread of infectious diseases and identify their causes. Analyzing large data sets helps epidemiologists identify risk factors and develop prevention strategies. However, there is no single structured database for Big data in the field of medicine in the country. Data is stored in different systems, making it difficult to analyze and compare.

5) *Augmented Reality (AR) and Virtual Reality (VR) technologies* are used in training medical workers, patient education, and in planning surgical operations and rehabilitation [220]. These technologies are actively used abroad; at present, in Kazakhstan, a sufficient number of products have not been developed that would fully use these advanced technologies.

6) *Nanotechnology and bioengineering* present enormous potential for medical advances, from diagnostics to drug delivery systems and tissue engineering. Small nanodevices and materials can specifically target specific cells or tissues, improving the precision and effectiveness of treatments [221]. At the same time, 3D bioprinting and tissue engineering technologies are currently being actively researched for organ transplantation and regenerative medicine [222]. However, despite several attempts to introduce these technologies in Kazakhstan, the projects have failed to make significant progress.

7) *mobile health – mHealth* refers to software interventions aimed at preventing, managing, or treating disease, which often use mobile applications, wearable devices, and sensors to deliver targeted behavioral and therapeutic interventions *[*223]. Kazakhstan has seen an increase in the use of wearable health monitoring devices, such as fitness bands and smart watches, which help track physical activity, heart rate, stress levels and other health indicators.

All seven areas are priorities for the development of MedTech in Kazakhstan and are aimed at improving the quality of medical care and the health of the country's population.

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

Highly developed foreign countries such as the US, Germany, Japan and China have mature and well-funded research communities that are producing notable breakthroughs in areas such as artificial intelligence, genetics, cell technology, etc. [224]. The US is a global leader in medical science and innovation, including genomics, neuroscience, biomedical engineering and telemedicine technologies. Germany is known for its research in medicine and biotechnology, including pharmaceuticals, molecular medicine and immunology.

Japan is famous for its research in medical technology and robotics, and there is also research in nanotechnology and biomaterials. South Korea is one of the leaders in the field of telemedicine, with Korean scientists actively working on the development of new medical devices such as smart prostheses, biosensors and tissue engineering technologies. China is actively engaged in research in the field of genomics and genetics, and is also actively using AI and big data analysis. These are just a few examples, and medical science and research in these countries continues to develop rapidly. On the other hand, scientific schools in Kazakhstan are focused on the study of infectious diseases, epidemiology and medical biotechnology. Kazakh scientists are also actively developing new methods for diagnosing and treating diseases. In particular, they developed the QazCovid-in vaccine against SARS-CoV-2 in April 2020, which was registered on the WHO website in May 2020.

The QazVac vaccine development program, successfully completed in 2022, represents a significant contribution to the development of Kazakhstani science and medicine. The vaccine has successfully completed two phases of clinical trials, which confirms its effectiveness and safety for use. This program not only led to the creation of an effective remedy against SARS-CoV-2, but as a result of its results a number of research articles were published in ranking scientific journals and security documents were obtained, which confirms the importance and quality of the research.

In recent years, Kazakhstan has made progress in the development and production of radiopharmaceuticals, strengthening nuclear medicine. Cooperation with Russia, the USA and France has led to the exchange of knowledge and technology, as well as increased qualifications of specialists and improved quality control. The country has a production site for the synthesis of radioisotopes used in theranostics at the Institute of Nuclear Physics of the Ministry of Energy of the Republic of Kazakhstan (INP). Sodium iodide ^{131}I is a drug for the diagnosis and treatment of thyroid cancer and thyrotoxicosis, produced at the Nuclear Physics Institute, registered, and has a safety certificate. The drug ^{153}Sm (153-samarium) is intended for palliative treatment of bone metastases of various locations. The production technology was developed at the Nuclear Physics Institute; preclinical and clinical studies are required to register the drug.

Kazakh scientists are also involved in oncology research, including early diagnosis, new treatments and the molecular biology of cancer. These studies are actively carried out within the framework of the scientific and technical progress of the PTF.

Priority VII – «Research in Education and Science»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

Kazakhstani science in the field of education is aimed at ensuring universal and equitable quality education, as well as lifelong learning for all. There is further development of international relations between Kazakhstani universities and foreign ones and the implementation of joint educational programs. It is noted that the formation of competencies is considered by researchers as the central core of language education.

The achievements of Kazakhstani science in the field of education and science can be characterized by the following parameters: publications in domestic and foreign scientific journals; in journals indexed in the Scopus or Web of Science databases.

Over the past 3 years, the most significant results were devoted to the following problems: benchmarking, «Rukhani Zhangyru», modern trends in professional training teachers for the inclusive education system, professional self-determination competencies, transformation of higher educational institutions through entrepreneurship in the context of digitalization, the use of media technologies, the use of digital games, a collaborative environment, scaffolding in subject and language teaching, linguocultural foundations of language teaching, linguocultural analysis and competencies, the role of academic spin-off companies in increasing the competitiveness of universities, freim arkyly sozdik qordy arttyru, Implementation of blended teaching techniques in academic English course, as well as qazaq makal-matelderindegi «ar – ozhdan» conseptisi.

The scientific interests of Kazakh scientists were presented in journals indexed in the Scopus or Web of Science databases. The most significant of them: social values of students in the context of digitalization of education and COVID-19, linguocultural anatomical code: the concept of sacredness, development of foreign language professional skills, formation of a multilingual personality, interdisciplinary ICT communications, formation of intercultural competence in teaching foreign languages, intercultural communication, use of information technologies, theoretical and methodological foundations of the Hyflex technology model.

The scientific interests of Kazakhstani scientists over the past three years have been presented in the following studies (based on the results of published monographs): pedagogy in the era of digital technologies; educational design in the 21st century; educational animation; distance learning in the digital era, pedagogical technologies and approaches to teaching language and literature in modern conditions, the content of education, ensuring the quality of higher education, the bestiary aspect of poetic fellinistics, linguocultural features of figurative language means in the Kazakh language, and the integration of science and education.

In other words, analyzing publications, monographic and dissertation research, we can note the main problems under consideration: modernization of the education system in the Republic of Kazakhstan, many studies are devoted to inclusive education, in 2022 many studies were refocused on more global studies, such as the transformation of universities, digitalization, concept sacredness, multilingual personality, spiritual development, linguocultural features, competitiveness of future teachers, cognitive competence.

The most significant implemented developments for 2020–2022: updated content of university programs, the use of augmented reality technology, the introduction of a dual system in the Republic of Kazakhstan, integration of the English language, yungogy, the values of the Kazakh education system in a multicultural and globalizing world, linguistic foundations for transcribing the onomastic names of Chinese language in the new Kazakh Latin alphabet, on the scientific basis of «Mangilik El», Kazakh zhane turik tilderindegi makal-matelder men matinderdin turkilik negizderi, kazakh paremasındağı ulttıq tanım jane olardıñ türki tilindegi paremalarmen baylanysy.

Scientific research before the pandemic was devoted to inclusive education, its accessibility, spiritual values and personal development; During the pandemic, there was a sharp reorientation of research on the problems of distance technologies and related problems of the quality of education. If we talk about research in the post-pandemic period, then, of course, most of the research was related to digitalization, scaffolding, spin-off companies in increasing the competitiveness of universities, and the formation of so-called «soft» and entrepreneurial skills. It is necessary to note the trends in the introduction of foreign practices in personnel training and, accordingly, the emergence of new trends in research: interaction with business, industry and industry, the introduction of dual training. New trends in education are influenced by various trends occurring in society, for example, the emergence of the Atlas of new professions has led to active developments in the field of so-called « supraprofessional competencies»: systems thinking, interdisciplinary communication, multilingualism and multiculturalism.

A common thread throughout all research over the past 3 years has been issues of continuous professional development and advanced training courses, for example (professional competence, educational technology, educational leadership, etc.).

In Kazakhstan, funding for science from the republican budget has almost doubled in the last two years [225], memorandums were signed with Coursera, Huawei, Binance Academy and Microsoft, 14 memorandums of understanding were signed between universities in Kazakhstan and France, JSC Center for International Programs with French partners [226].

Over the past three years, the following works have been awarded the Y. Altynsarin Prize for the best scientific research in the field of pedagogy: «Philosophical methodological problems of Kazakh linguistics», A. Trushev (NJSC «Toraigyrov University» , 2020); «Greenization of the university education system as an innovative way to modernize the spiritual consciousness of students» Dlimbetova G.K., Bulatbaeva K.N., Rakhimzhanova M.M., Abenova S.U., Akimish D.E. (ENU named after L.N. Gumilyov, 2021); «Kazakhstan Republikasynyn enbek kukygy» (Okulyk) Apakhaev N.Zh. (Kainar Academy, 2022); M. Auezov Prize for the work «History of the Germans of Southern Kazakhstan» (c. XIX – c. XX centuries) Apendiev T.A. (Al-Farabi Kazakh National University, 2021).

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

The Open University educational technology institute, in tandem with researchers from the National Institute for Digital Education from Dublin City University, developed the top 10 innovations in the field of pedagogy in 2020 [227]. Among them are artificial intelligence in education, learning using open data, learning through animation, multisensory learning, and online laboratories. In 2021, the global community talked about such trends as lifelong learning, total digitalization, online courses, gamification of education, augmented and virtual reality, project work, adaptive learning, and neurotechnology. Innovations in pedagogy that have gained popularity in 2022 [228]: hybrid learning, dual (or practice-oriented) learning, micro-degree pedagogy, influencer learning, autonomy pedagogy.

One of the key trends today is the integration of technology into the language teaching process. The use of interactive programs, mobile applications, online resources and social networks is becoming more common. Researchers such as Johnson & Thornburg have found that the use of multimedia materials and technologies such as virtual reality can increase students' motivation and improve their language skills [229]. Also, the transition from traditional teaching to active and practical learning, communicative and interactive tasks, games, situations [230]. Another important trend is the transition from a narrow focus on grammar and vocabulary to the development of communicative competencies and intercultural literacy, project-based learning aimed at developing speaking, listening, reading and writing skills, as well as cultural understanding [231].

Top innovations in Kazakhstani science - education and innovation for digital transformation. According to experts, in a few years digital education will become a market with a turnover of $1 trillion (~ 10% of the total global education market) [232]. Further mention can be made of video technologies, electronic library systems; educational digital (computer) programs; interactive technologies; constructors for creating online quizzes, multimedia, video conferencing.

For the first time in the last three years, annual spending on scientific research in Kazakhstan increased by 22.8%. 86 billion tenge has been allocated for grant funding of scientific projects for 2023-2025.

In 2020, domestic universities took part in the implementation of more than 300 international projects.

The most significant aspects of cooperation over the past 3 years have been the following. In 2020, the Rome Communiqué was adopted, within which three directions are updated: inclusive, innovative, interconnected [233]. But due to the situation that occurred in 2020 amid the COVID-19 pandemic, the implementation of the program for attracting foreign specialists to teaching activities at the expense of budget funds was suspended, cooperation involving the creation of an open online course within the framework of a MOOC on the platform of the University of Zurich in collaboration with the University Lausanne in Switzerland, the

University of Constance in Germany, the University of Zagreb in Croatia, St. Petersburg State University of Russia and KazNPU named after. Abay (L.V. Safronova), organization of training seminars with Gazi University, Kozatepe University (Turkey), Turkic scholar Hussein Kaharman Mutlu on the topic «Turkic civilization: language, literature and history» (KazNPU named after Abay).

Among the significant international projects the following can be noted:

On the basis of the International Scientific Laboratory for Problems of Informatization of Education and Educational Technologies, an international scientific project was implemented on the topic «Development of a system for preparing teachers for teaching and educating schoolchildren in the conditions of digitalization of society» together with Moscow Pedagogical State University (MPSU), Moscow State University (MSU) and Krasnoyarsk State Pedagogical University (KSPU) named after V. Astafiev (Doctor of Pedagogical Sciences, Professor, Academician Bidaibekov E.Y.).

The British Council finances 4 projects, of which 5 universities of Kazakhstan (Almaty Management University, Kazakh National Academy Of Arts named after T.K. Zhurgenov, KAFU, KBTU, Kazakh-Russian International University) participate in 1 project «Creative Spark: entrepreneurial program in the field of higher education». 1 project is being implemented by Atyrau University named after H. Dosmukhamedov on distance learning of English in Atyrau, a project of the American Partnership of Universities of the USA and the Republic of Kazakhstan on the topic «Integration of English in higher education pedagogy: partnership between South Kazakhstan University named after. M. Auezov (SKU) and the University of Minnesota».

In 2021–2022, a number of universities participated in the implementation of international projects carried out in accordance with the Erasmus+ program: the project «Strengthening potential in the field of higher education» (Zhezkazgan University named after O.A. Baikonurov), «Implementation of the Dual System in Kazakhstan» (KazNPU named after Abay), «Development of Skills and Teachers Training for Leadership», Implementation of Education Quality Assurance System via Cooperation of University-Business-Government in HEIs SILKRoad Universities Towards Europe ((KAUIR&WL named after Abylay Khan). There are also projects within this program aimed at development and modernization of curricula, teaching methods, improvement of management and leadership of universities, strengthening communications between universities. Within the framework of the Erasmus+ work, one can note the Jean Monnet projects in Kazakhstan: Digital humanities in the Republic of Kazakhstan: local solutions to global problems (Al-Farabi Kazakh National University, Center of Excellence (Kostanay Engineering and Economic University named after M. Dulatov). Priorities of this program: inclusion and diversity, digital transformation and participation in democratic life, civic engagement.

Among others programs scientific initiatives Can note TEMPUS: «Documentation for Quality Assurance of Study Programs (DoQuP)», «STUdents self-governance & Democratic Involvement in Kazakhstan (STUDIK)» TACIS project «Social Education and Communication» (KAUIR&WL name Abylai khan).

A number of other agreements on the implementation of research work with international scientific organizations can be noted: Federal State Autonomous Educational Institution of Higher Education «National Research University «Higher School of Economics» (National Research University, Higher School of Economics, Russia) (KazNPU named after Abay, implementation period 2019–2021); international project through British Council «Online Teacher Community Program for Pre - service Students». Facilitators from SKU named after. M. Kozybaeva: Vasilyeva O.M., Olkova I.A., November 2022 – March 2023; «Synergetic foundations and heutagogy for personal self-development and the development of spiritual and moral qualities» 2022; Study of trends in factors influencing educational migration from Kazakhstan «Educational migration from Kazakhstan: trends, factors and socio-political consequences» 2021 (Al-Farabi Kazakh National University).

International grant projects for 2021–2022, funded by the US Embassy: «Media literacy as the key to the formation of a competent society of media consumption among teenagers, professional journalists and university teachers to increase society's resistance to information», a project from the British Council (British Council) «Developing a partnership strategy between two universities» (Kazakhstan-American Free University).

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

The presence of scientific schools is one of the most important characteristics of the state and development of science. These are advanced organizational forms of science that make the main contribution to the development of the country's intellectual potential [234,235].

The most significant achievements of Kazakhstani scientific schools in the following areas: informatization of education and educational technologies - research in this area served as a powerful impetus for the formation and development of the theory and methodology of teaching computer science and informatization of education in Kazakhstan (Doctor of Pedagogical Sciences, Professor, Academician of RAE Bidaibekov E.Y.); national education and self-knowledge of student youth; methodology and strategy for the development of a system of continuous pedagogical education; methodology and didactics of subject teaching methods and the formation of methodological thinking of students; improving professional teacher training , leadership in education, dual education, national education, etc. (Doctor of Pedagogical Sciences, Professor Zhampeisova K.K.; Doctor of Pedagogical Sciences, Professor, Academician of the National Academy of Sciences Abylkasymova A.E.; Abdigapbarova U.M. etc.), a scientific school in the field of modern Kazakh language (Orazbayeva F.Sh., corresponding member of NAS RK), research into the creativity of Alash figures, Shakari studies; the concept of literary text as a system; cognitive linguistics, comparative linguistics; psychoanalysis in literature and literary criticism; cognitive literary studies; linguistic aspects of translation studies and intercultural communication (Abdigaziuly B., Abisheva S.D., Musataeva M.Sh., Safronova L.V., Zhumabekova A.K.)

The most significant contracts for the implementation of research over the past 3 years: «Yunogogika: theory and practice of youth work in the conditions of youth work in the conditions of modernization of public consciousness» (PhD. Teslenko A.N.), «Scientific and pedagogical foundations for creating a mobile applications for parents for psychological and pedagogical support of children of preschool and school age»; «Internationalization of higher education in Kazakhstan: future directions» (Kyzylorda University named after Korkyt Ata); «Pedagogical Universities Development Project» (Olkova I.A.), «Scientific and methodological foundations for teaching expressive speech in the context of implementing the content of updated education in national schools (based on the secondary education system)» (Mukhamedzhanova G.T.), «Methodology application of augmented reality in the development of programmed digital educational resources», «Training of special teachers for psychological and pedagogical support of children with disabilities in the conditions of inclusive education» (Pavlodar Pedagogical University named after A. Margulan).

Priority VIII – «Research in the field of social and human sciences». Section «Research in the Humanities»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments)

Reconstruction of the development of modern Kazakh humanitarian knowledge and philosophy shows both the presence of innovative trends and its deep rootedness in the traditional way of mythopoetic philosophizing of Kazakh and Turkic culture, language, and history. The subject of comprehension at the turn of the 20th and 21st centuries were the processes of national construction and associated changes of a socio-economic nature, value transformations and the emergence of the information society, linguistic aspects of the formation of Kazakhstan's cultural discourse. Kazakh scientists have solved the problem of interpreting and explaining the changed symbols of culture and vital issues of the social existence of society. In the works of Kazakh scientists (Zh.A. Altaev, G.G. Barlybaeva, G.G. Solovyova, S.B. Bulekbaev, T.Kh. Gabitov, G. Yesim, A.K. Kasabek, S.E. Nurmuratov , G.Z. Nurysheva, A.N. Nysanbaev, A.T. Taizhanov, G.T. Telebaev, M.Sh. Khasanov, S.Sh. Ayazbekova, S.A. Ayazbekov, etc.) mythological and historical – the cultural foundations of the formation and development of the philosophy of the Kazakh people from the point of view of modern values, the value-semantic aspects of the national type of philosophical research are revealed, the spiritual and moral potential of culture and values is determined in the conditions of the new Kazakh reality and the challenges of sustainable development.

Philosophical Studies. During the period 2020–2023 Kazakh scientists and leading research centers developed almost all areas of philosophical research, including the history of Kazakh, Turkic and world philosophy, social and political philosophy, axiology, ethics, Farabian studies, etc. [236].

History of Kazakh philosophy. Of all the variety of trends in modern philosophy, the study of the history of national philosophy is of particular interest. Research emphasis in the field of history of Kazakh and Turkic philosophy and culture in 2020–2022 shifted towards the search for the spiritual foundations of modernization, updating such concepts as the ideology of political unity, preservation of land and culture, humanism [237], justification of the value core of social consciousness [238], comparative analysis [239]. The task of in-depth study of the Turkic roots of Kazakh philosophy was implemented [240], and research was carried out on the spiritual and cultural potential of the philosophical and poetic heritage of the Kazakh people. In the discussion of these issues, attention is drawn to the cultural, phenomenological and socio-philosophical analysis of the phenomenon of Tengrism in history and modernity [241].

Abay and al-Farabi. In 2020–2022 the number of publications in the field of Farabi studies has increased [242], as well as those devoted to the work of Abai [243], which is determined by the fact that in 2020, under the auspices of UNESCO, a year of celebration of the anniversaries of two great thinkers of the East took place in Kazakhstan - the 1150th anniversary of Abu Nasr Muhammad al-Farabi and the 175th anniversary of Abai Kunanbayev. In this scientific direction, there is a tendency to reduce the number of innovative works, generalization and systematization of individual topics, while other problems remain unattended. Among the achievements in the field of Farabi studies, it is necessary to note the works of E.Y. Bidaibekov, devoted to the interdisciplinary analysis of the mathematical heritage of al-Farabi, as well as the study and popularization of the achievements of Kazakhstani Farabi studies, revealing the true image of al-Farabi as a mathematical thinker, theorist and practicing astronomer, researcher of other natural sciences, in particular in the works of A.Kobesov [244]. In 2020, Kazakhstan Farabi scholars also published a number of fundamentally new materials, translations of al-Farabi's heritage in the works of Zh. Sandybaev, A.A. Mustafaeva, Y.M. Paltore, K.H. Tadzhikova etc. [245].

Axiological research and ethics. Of particular importance in the field of modern humanitarian research is a comprehensive assessment of ideological and spiritual values. In the speech of the President of the Republic of Kazakhstan K.K.Tokayev at the second meeting of the National Kurultai in Turkestan notes: «We must continue our movement forward and constantly work to strengthen our values...» [246]. Within Longitudinal axiological research of the creative team of the Institute of Physical Education and Science of the Kyrgyz Republic of the Ministry of Education and Science of the Republic of Kazakhstan obtained scientific results that reveal the significance of the values of Kazakh society and the features of the current state of Kazakh value discourse and ethics [247].

Political Science Research. The current stage of development of political science in Kazakhstan is associated with the transformation of state institutions, under the conditions of which the dependence of the effectiveness of public administration on the quality of analytical support becomes obvious. The main trends and achievements in the development of political research over the past three years are:

– intensive development of applied political research;

– development of recommendations for identifying ways to prevent or resolve various conflicts, assessing factors in the formation of the protest potential of the regions of the Republic of Kazakhstan, conducting election campaigns and developing political technologies, developing and making decisions on significant socio-political topics, etc. [248];

– further active development of academic political science, which is characterized by fundamental theoretical developments in such subject areas as modern philosophy of politics, ethnosocial studies, etc.

With regard to applied political analytics, it is worth highlighting the development by political science experts of issues related to political risks, the study of issues of democratization, interaction of the state with civil society institutions, and foreign policy issues. At the same time, these studies remain in demand to a greater extent within the scientific and academic community, and expert activity is carried out unsystematically. As emphasized in the speech of the President of the Republic of Kazakhstan K.K. Tokayev, in Kazakhstan there is a need to form a network of expert and analytical centers, within the framework of which an analysis of all areas of development of our country should be carried out.

Religious Studies and Islamic Studies. Analysis of the achievements of Kazakhstani science in the field of religious studies allows us to determine the following most promising directions of its development and results:

– further development of fundamental research in the history and phenomenology of religion, understanding of the institutionalization of religion, its functions and capabilities in a multicultural, multi-confessional society and a secular state; philosophy of religion and religious philosophy, secular studies, etc.

– implementation of applied and interdisciplinary research on current problems of religious experience: (1) sociology of religiosity in non-confessional and confessional contexts; (2) psychology of religion and problems of minimizing the risks of extremization of religious practices; (3) analysis of religious conversion trends; (4) comparative studies of traditional and new religiosity and the phenomena of quasi-religiosity, etc.

– updating Islamic studies as an interdisciplinary humanitarian knowledge that has significant potential for studying Islamic scientific discourse, assessing the sustainability of Islamic identity and tolerance, Islamic education, as well as developing a strategy for the prevention of Islamic radicalism, and the formation of state policy in the field of religion.

In 2020–2022 monographs have been published on the problems of the relationship between secularism and religion, inclusiveness and exclusivity of religious identity in modern Kazakhstan, the history of religions on the territory of modern Kazakhstan [249], a number of works have presented an in-depth analysis of the problems, trends and prospects of modern Islamic philosophy, the cognitive interpretive resource of including modern Islamic philosophy in the intellectual and educational space of Kazakhstan [250].

It should be noted separately that Kazakh scientists have implemented the interactive project «Interactive Religious Map», aimed at optimizing the monitoring of the religious situation in the city of Almaty and which has been implemented for several years [251].

Sociological Research. Currently, in accordance with the most pressing problems and challenges of modern civilization, the range of Kazakhstani sociological research has expanded significantly. Among the most promising areas of sociological research in the last 3 years, several areas dominate: the social structure of society, ethnosociology, sociology of migration, youth studies, sociology of the family, economic sociology, as well as the study of socio-political changes and socio-cultural identity [253].

The topics of sociological research are extremely diverse and cover almost all spheres of social life. In recent years (2020–2022), a number of works by Kazakh sociologists have been published (K.U. Biekenov, K.G. Gabdullina, Z.K. Shaukenov, S.E. Dzhamanbalaev, G.S. Abdirayimova, G.O. Abdikerova, M.S., Sadyrova M.S., etc.) on the theory and methodology of modern sociology [254].

Since 2022, on the website of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, brief results of the 2021 National Population Census [255] in the Republic of Kazakhstan are available, however, the presented content is incomplete, which in turn limits the possibilities of further analytics and expertise required by modern Kazakh society.

Linguistics. Kazakhstani linguistics, as part of world linguistics, is developing in a polyparadigmatic aspect, in which the language itself is understood as a dynamic, historically established sign system, which is a means of not only communication, but also cognition.

At the Institute of Linguistics named after. A. Baitursynov, within the framework *of the National Corpus of the Kazakh language,* new sub-corpora are being developed: the Kazakh-Russian parallel sub-corpus, which covers parallel works in the Kazakh and Russian languages , a sub-corpus of Kazakh oral speech, annotated on the basis of voiced audio texts , a sub-corpus of Kazakh historical texts, reflecting the written historical heritage [256].

As part of the program for the transition of the Kazakh language to the Latin script, a number of onomastic rules were developed in order to unify the transfer of geographical names of Kazakhstan and foreign countries; for the first time, principles of spelling of geographical names and names on the territory of Kazakhstan were developed in accordance with the new Kazakh alphabet [257]. Research work in the field of lexicology is carried out in three directions: historical, traditional-structural and anthropocentric lexicology. In order to popularize the Kazakh language, a page « qazsozalem» has been opened on Instagram with an illustrative presentation of Kazakh words.

Historical research is being conducted to identify Arab-Persian words, which are one of the elements of the Kazakh literary language. «An explanatory dictionary of Arabic-Persian words in Cyrillic and Latin scripts» has been developed, which included semantic changes in words related to the needs of modern reality [258].

A new direction of modern Kazakh linguistics - *Akhmetology* - is aimed at studying the scientific heritage of the founder of national linguistic science, reformer of the Kazakh language Akhmet Baitursynov in the light of modern linguistic trends and methods. In this regard, the international scientific conference «Akhmetological Readings» is regularly held; in 2021, in honor of the 150th anniversary of A. Baitursynov, a graphic projection of 3 editions of the textbook «Til-Kural» in Cyrillic was developed and published in order to popularize the scientific heritage of A. Baitursynov developed and launched the «Ahmettanu» website (https://ahmettanu.kz/).

Main aspects of the development of economic science in the Republic of Kazakhstan. Policy in the field of economic science in Kazakhstan is an integral part of the general socio-economic policy of the state, which reflects the attitude towards science, technology and innovation in the economy, determines the goals and plans of the relevant government bodies for the development of the state's knowledge-based economy.

The country has developed a comprehensive regulatory framework and created public administration structures to ensure the effective implementation of STI policies. The focus is on supporting the development of an innovation ecosystem to encourage innovation across all sectors.

A special role in the further development of fundamental and applied economic science is played by the principles and provisions of the Address of the Head of State K.K. Tokayev to the people of Kazakhstan «A Fair State. One nation. Prosperous society» (dated September 1, 2022), in particular priorities: new economic policy, development of the real sector, strategic investments in the future of the country, reboot of public administration. The publication pool of scientific research results of applied economics is typical only for research institutes and universities, but the latter face difficulties in accessing information, including information on the results of research and innovation projects carried out with government support, as well as commercial information on market development trends, etc.

In order to identify key challenges and problems in the field of increasing the efficiency of the formation and development of applied economics, a total of 41 respondents were recruited and interviewed, representing various institutions, companies and bodies (government officials, representatives of academia, the research community, business circles and non-governmental organizations), as well as representatives of civil society.

All interested experts participating in the survey emphasized:

– the importance of introducing scientific support and strengthening the role of applied economics in the process of strategic planning and implementation of large-scale developments to improve the efficiency and effectiveness of key sectors of the economy;

– a high degree of importance of the development of applied economic science, the relevance and necessity of scientific progress in the sustainable development of the country;

– the lack of a well-thought-out strategy at the country level (master plan) for the development of STI and poor coordination of plans of various ministries and departments. Characterized by a general short-term focus of plans, frequent changes in priorities and changes in the leadership of institutions involved in the formation and development of applied economic science;

– the lack of an integrated system of coordination, monitoring and evaluation of policy results in the field of applied economic science creates the problem of low efficiency in the implementation of strategies, concepts and plans;

–insufficient level of development of cooperation between institutions dealing with issues of applied economics, ministries and departments, which in the process of carrying out their activities do not interact with the scientific community, which reduces the effectiveness of the implementation of economic reforms;

–low level of involvement of the scientific potential of research institutes and universities of the country in the research of line ministries and departments in the preparation of decisions. There is practically no mechanism for involving doctoral students and university teaching staff in research and resolving issues of the results of applied economic science from ministries and departments.

Many respondents emphasized the importance of the participation of the scientific community in conducting, on an ongoing basis with the supervising departments, research at the fundamental and applied level, recommendations of the IMF, World Bank, European Bank for Reconstruction and Development, Asian Development Bank on structural reforms for the Government of the Republic of Kazakhstan. When placing orders for research on the economic policy of Kazakhstan to international experts, the Government could also place an order for this research to the Kazakh scientific and expert community.

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

The development of modern humanities research is distinguished by both a significant number of schools and directions, and regional diversity against the backdrop of the increasing role of philosophy in the era of globalization. UNESCO's position on issues of philosophy is expressed in a number of documents in which, since the mid-twentieth century, a program for the development of philosophy has been developed, the relevance of the main provisions of which is undeniable even today. The priorities for the development of philosophical research and academic philosophy are consistently defined in the «Paris Declaration on Philosophy» (1995), «UNESCO Intersectoral Strategy in the

Field of Philosophy» (2005), «UNESCO Science Report. Racing against time for smarter development» (2021).

International cooperation of Kazakh universities and scientific organizations in the field of humanities and social sciences (philosophy, sociology, political science, religious studies, linguistics, etc.) is carried out within the framework of the work of public associations of Kazakh scientists, such as the Kazakhstan Philosophical Congress (KPC), the Association of Sociologists Kazakhstan» (ASK), etc.; conducting international scientific research and implementing social, scientific and cultural projects; organization of joint and double-degree educational programs; implementation of management of scientific research of PhD doctoral students, membership in international organizations, etc. All areas have their own formats of international cooperation.

Thus, on October 14–15, 2021, the next VII Congress of Sociologists of Kazakhstan «Independent Kazakhstan: Social Changes and Future Prospects», dedicated to the 30th anniversary of the Independence of Kazakhstan, was held in the format of an expert meeting. The Forum discussed the fundamental changes that have occurred in Kazakh society in recent years, the problems and difficulties of modern Kazakh sociology, the need for high-quality sociological support of state policy, etc. [252].

The public association «Kazakhstan Philosophical Congress» is a member of the World Federation of Philosophical Societies - FISP. Scientists from Kazakhstan participated in the work of the XXIV World Philosophical Congress in Beijing (China, 2018), the Russian Philosophical Congress in Moscow (2022). The result of the participation of Kazakh philosophers in international congresses is recognition of the achievements of fundamental scientific schools of dialectical logic and Farabian studies, presentation of scientific works devoted to Kazakh philosophy, methodology of science, understanding of modern problems of socio-political life and socio-humanitarian development of Kazakhstan, etc.

Institute of History and Ethnology named after Sh. Ualikhanov for 2020–2022. Memorandums of cooperation were signed with 136 scientific, educational and cultural organizations (57 of them with foreign ones). In particular, joint research work is being carried out with Kyrgyz, Russian partners, and Poles. In 2022, the Kazakh-Kyrgyz Association of Historians and the Polish-Kazakh Historical Commission were created. Their activities are carried out on a voluntary basis and are not funded by certain government agencies or organizations.

At the Institute of Linguistics named after. A. Baitursynov the International Section on Psycholinguistics has been created. The consultant of the section is a Russian scientist in the field of neuroscience and psycholinguistics, as well as theory of consciousness, Doctor of Biological Sciences, corresponding member of the Russian Academy of Education T.V. Chernigovskaya. Several international conferences have been held on theoretical and applied problems of psycholinguistic description of the content of linguistic units.

International projects and programs are an effective factor in the development of international cooperation and recognition. Thus, a collaboration of scientists from the Department of Sociology and Social Work of KazNU named after. al-Farabi with the Global Health Research Center for Central Asia at Columbia University allowed Kazakh scientists to participate in social research projects aimed at population groups most at risk, as well as the protection of children in migration processes with the assistance of UNICEF (2021).

The most important factor in increasing the potential of Kazakhstani science and education was the implementation of the project «New Humanitarian Knowledge. 100 new textbooks in the Kazakh language» [259]. The books by Anthony Kenny «The Recent History of Western Philosophy», George Ritzer, Jeffrey Stepnitsky «The Theory of Modern Sociology» , Karen Armstrong « The History of God: 4000 Years of Quest in Judaism, Christianity and Islam» and many others have been translated into Kazakh and are actively used in the educational process, and in the next three years, more than 50 new educational and scientific materials have been translated and introduced into the educational and research process. The use of project results in the educational process and scientific activities made it possible to focus on the latest achievements, update the content of disciplines, provide access to electronic textbooks in both Kazakh, Russian, and English languages, for groups with the appropriate language of instruction, etc.

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

The leading research centers in the field of philosophy and the humanities are (Institute of Philosophy, Political Science and Religious Studies of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (IPPSaRS SC MES RK), Al-Farabi Kazakh National University (Al-Farabi KazNU), Karaganda State University named after E .A. Buketov (KarSU named after E.A. Buketov), Eurasian National University named after L.N. Gumilyov (ENU named after L.N. Gumilyov) International Kazakh-Turkish University named after Khoja Ahmed Yassawi (IKTU named after Kh. A. Yassawi) and others), Egyptian University of Islamic Culture Nur-Mubarak. In the field of linguistics - Institute of Linguistics named after. A. Baitursynov, Kazakh State University of Music and Moscow State University named after Abylaikhan and others.

In recent years, the research infrastructure has expanded significantly at both the republican and regional levels. For example, the Economic Research Institute under the Ministry of National Economy (ERI), the Center for Socio-Political Research « Alternative» , the «Assessment Risks Group» , the Center for Sociological Research and Social Engineering of KazNU. Al-Farabi, Scientific Research Center « Molodezh", Coordination Center for Language Research at the Abai KazNPU, Research Institute of Turkic and Altaic Studies of the KazNU named after. Al-Farabi and others. The leading one in the field of socio-political research remains the Kazakhstan Institute for Strategic Studies under the President of the Republic of Kazakhstan (KISS).

Within the framework of historical science, leading scientific schools have been formed: on the historical demography of Kazakhstan under the leadership of

Asylbekov M-A.Kh.; leading scientist in the study of the Kazakh national liberation movement Koigeldiev M.K., under whose leadership the project «Alash Movement». Documents and materials was created. Currently, under his scientific leadership, a twelve-volume collection of documents entitled «Alashorda Case. Documentation» is being prepared.

The founder of the scientific school of ethnological specialists is an ethnologist, archaeologist, Doctor of Historical Sciences, professor, corresponding member of the International Academy of Architecture of Eastern Countries, chief researcher at Sh. Sh. Ualikhanov, Azhigali S.E. – specialist in history and culture, monuments of the Eurasian steppes, folk architecture and ethnography of the Kazakhs. Deals with issues of historical nomadism, oriental studies, and diaspora.

The profile of economic science is formed and implemented on the basis of the activities of the RSE Institute of Economics of the SC MES RK and university science, private centers, foundations through participation in projects of the Global Fund of ministries, the implementation of doctoral programs in economics and cooperation with foreign universities and research institutes.

Basic and applied scientific research.

Modern Kazakh philosophy is represented by analytical works on the history of philosophy, understanding of trends in the field of modern spiritual culture and value consciousness, as well as new approaches to the analysis of individual topics in social science.

In the project's boundaries *«Spiritual and cultural potential of the philosophical and poetic heritage of the Kazakh people at the modern modernization stage of development of Kazakhstan»* (IPPSaRS SC MES RK) in 2022, historical time and space, the worldview of the nomads of the Great Steppe, who were presented to the world in a syncretic form - history, language, art, culture, worldview and spirituality in general, were critically comprehended at a philosophical level. The possibilities and advantages of transdisciplinary synthesis are demonstrated by the research project «*Religiousization processes in Kazakhstan: specifics, trends, impacts on the development of society and human capital (interdisciplinary analysis)»,* which, through the means of socio-humanitarian sciences (religious studies, sociology, political science, philosophy) based on specific social measurements reveals the process of religiosization of Kazakhstani society, its specifics, trends, institutional impacts, social risks.

It should be noted the social significance of the results of two large scientific programs implemented with program-targeted funding on the basis of the Institute of Philosophy, Political Science and Religious Studies of the National Science Ministry of Education and Science of the Republic of Kazakhstan:

– Within the framework of the program *«Study of culture and values of society in the context of the sustainable development strategy of Kazakhstan» (*2021–2022), a comprehensive study of sociocultural, political, ideological prerequisites, factors and conditions for the development of culture and values in the context of the modernization of Kazakhstani society was carried out and practical recommendations were developed -oriented recommendations on cultural issues.

– The scientific program *«Social modernization of Kazakh society: ideological and ideological foundations, conceptual models, sociocultural processes, socio-political technologies*» (2021–2023) made it possible to study the dynamics of quantitative and qualitative changes in the social structure of Kazakh society. The research material of the project fills a significant lack of information on the issue of trends in the development of the social structure of modern Kazakh society, forecasting its transformation in the conditions of modernization and post-industrial development.

For 2020–2022 The following significant nationwide results from the implementation of scientific projects were obtained:

– a reconstruction was carried out to *the concept of an integral and universal person («tolyk adam») in Abai's philosophical teachings, world and national cultural archetypes in Abai's works were identified* (IPPSaRS SC MES RK, ENU named after L.N. Gumilyov);

– an interdisciplinary study of the trends of modern Islamic philosophy of the postmodern era was implemented to form an intellectual hub of new humanitarian knowledge in Kazakhstan (IPPSaRS SC MES RK) .

– the specification of qualitatively different aspects of the existence of religion in modern society and the processes of transformation of religious practices is presented based on the results of the implementation of the projects *«Hanafi tradition in Central Asia and the foundations of Kazakh spirituality»* (MKTU named after H. A. Yasawi) and «*Missionary activities in the Internet space and its role in the formation of the religious consciousness of the youth of Kazakhstan*» (Al-Farabi Kazakh National University), *«Secular and religious values in modern Kazakhstan: interaction and influence on the policy of the Republic of Kazakhstan in the field of religion» and «Religious aspects of traditions and innovations in Kazakhstan: past, present and prospects» (*IPPSaRS SC MES RK).

– important practical results were obtained by Kazakh political scientists within the framework of the projects *«Protest potential in Kazakhstan: features, factors and trends»* (2020–2022, Al-Farabi Kazakh National University) and *«The influence of digitalization on the political culture of Kazakh youth»* (2021–2023, IPPSaRS SC MES RK).

At the Institute of Linguistics named after. A. Baitursynov 2 scientific programs were implemented within the framework of targeted funding in 2020–2022: *« Development of a series of updated standard dictionaries and academic publications that ensure the translation of the state language into the national Latin alphabet» (2020–2022)* and *«Development of the National Corpus of the Kazakh language as an information and innovation base of the state language: a research and teaching Internet resource» (2021–2023).* A comprehensive multidimensional study was carried out to improve the updated normative, orthological corpus base of the state language based on the new national Latin alphabet. In general, the results obtained will contribute to increasing the role of the Kazakh language in the digital space.

An important achievement of the historical science of Kazakhstan was the holding in 2017–2020, on the basis of the Institute of History and Ethnology named after Sh. Sh. Ualikhanov, together with the Institute of Information and Computing Technologies and the Institute of Geography, *researched to create and fill out an interactive scientific historical map «The People of Kazakhstan».* The map was developed in 2017 on behalf of the Head of State in order to visually represent the processes of formation of the multinational population of Kazakhstan and was presented on Gratitude Day on March 1, 2018.

2018–2020 as a result of the implementation of the scientific program, *the « Encyclopedia of the History of Kazakhstan»* (in Kazakh language) was published in 3 volumes.

In 2022, as part of the work of the State Commission for the complete rehabilitation of victims of political repression, with the participation of domestic historians, a collection of documents *«Materials of the State Commission for the complete rehabilitation of victims of political repression» was published* in 31 volumes. During the implementation of the work of this commission www.e-memory.kz, a database of victims of political repression was launched on the site platform. Currently, in 2023, 12,876 people are included in the list of victims of repression. New information materials have been included in all sections of the site, and work has begun to fill out the database of victims of repression.

Priority IX – «Sustainable development of the agro-industrial complex and safety of agricultural products»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments

1.1 Development of intensive livestock farming.

The extent of homozygous regions was studied (ROH, Runs of Homozygosity) on the characteristics of distribution and frequency in the genome of the Kazakh white-headed and Auliekol breeds of cattle. The results showed that shorter ROHs occurred in both cattle populations than long ones. Genomic inbreeding coefficients F_{ROH} showed higher rates of ancient inbreeding compared to recent inbreeding coefficients. Further research into ROH will provide broader applications in the search and identification of genomic regions associated with selection pressure, called selection signatures [260].

An enzyme-linked immunosorbent test system has been created for early diagnosis of pregnancy in cows [261]. The use of the development will make it possible to identify pregnant cows already on the 30th day after insemination with the reliability of the results obtained being 98%. The introduction of the developed test systems will significantly increase control over the effectiveness of artificial insemination of cows and improve the reproduction process in breeding work.

On dairy farming. The influence of genotypes of the bGH and bIGF-1 genes on the milk productivity of black-and-white cows was studied. The bGH -AluI ^{LV} was identified as preferable for black-and-white cows, associated with higher milk production. The use of allelic variants of the *bGH gene* allows direct selection of animals at the DNA level as an additional criterion. To increase milk productivity in herds, it is recommended to use cows with the genotype bGH - AluI ^{LV}, descended from black-and-white sires of the Wis Burke Ideal line. The preferential use of sires carrying the bGH – AluI ^{LV} will increase the milk productivity of black-and-white cows [262].

The genetic structure of the Baysar sheep breed and its ancestral breeds was studied using Ovine SNP50K markers, as well as phenotypic traits. The results obtained can be used as a basis for studying fat-tailed sheep breeds at the genomic level and developing sustainable programs for preserving the genetic diversity of Baysar sheep in the future [263].

On digitalization in livestock farming. Within the framework of scientific and technical programs for 2021–2023. The Ministry of Agriculture of the Republic of Kazakhstan is completing research: on the development of new feeding and reproduction standards for dairy cattle in Kazakhstan based on NRC standards under a license agreement from the US National Academy of Sciences; on developing our own system for selection in beef cattle breeding for paying for feed by growth based on advanced technologies (GrowSave, Canada and Intergado, Brazil); on the development of a domestic system for remote control (tracker, communication system, including without cellular communication) of horses during year-round grazing [264]. A smart pasture system has been developed that allows solving a number of technological processes (identification control, daily live weight analysis, veterinary welfare, animal processing, watering control) without human intervention.

1.2 Ensuring veterinary safety.

A brucellosis enzyme-linked immunosorbent diagnosticum has been developed based on a genetically engineered recombinant antigen (RK Patent № 35776), which is superior in its effectiveness to foreign analogues available on the veterinary drug market [265, 266].

Using the Cas12a enzyme produced by the microorganism strain Escherichia coli Arctic Express (DE3)/MbCas12a [261–267], a kit was produced for isolating genomic DNA of pathogenic bacteria (staphylococci, Escherichia coli and streptococci) from milk with a sensitivity of 10 3 ^{CFU} /ml, determined optimal parameters and specificity for determining the DNA of microorganisms in milk based on CRISPR/cas technology (high speed and accuracy of selective detection, ease of use, does not require additional equipment).

The epizootological characteristics of the country's territory for peste des petits ruminants and bluetongue were determined, the risks were assessed, and the territory of the Republic of Kazakhstan was zoned and regionalized according to the degree of intensity of the epizootic situation. Using a complex epidemiological model based on a mathematical-geographical approach to assessing the expected localization and scale of outbreaks in the retrospective period and the current time, scenarios were developed to predict the possible development of the epizootic situation for infectious animal diseases, taking into account the influence of various biotic and abiotic factors [268,269] .

Investigated infections of bovine leukemia virus BLV, which causes enzootic leukemia (EBL), registered in Kazakhstan, identified and assessed the level of BLV proviral DNA using quantitative PCR in DNA samples of 119 naturally infected cows from 18 farms located in four different geographical regions of Kazakhstan [264–270]. Phylogenetic and molecular analysis of 41 BLV env-gp51 gene sequences was performed. Phylogenetic analysis showed that the sequences belong to two already known genotypes G4 and G7, as well as to a new genotype classified as genotype G12. Provides up-to-date data on the epidemiology of BLV infection in Kazakhstan, including an analysis of risk factors that will help develop and implement effective BLV control plans in Kazakhstan.

Genome-wide molecular analysis of two batches of the Lumpivax vaccine was carried out against lumpy skin disease virus (SDV). The results revealed that the Lumpivax vaccine is not a pure Neethling-based SDV vaccine, but a complex mixture of several CaPVs, which has caused the emergence of vaccine-like strains of LSDV in large parts of Asia, apparently resulting from the spread of the virus from animals vaccinated with the Lumpivax vaccine [271]. This study demonstrates the advantage of using high technology based on whole genome/high throughput WGS/HTS sequencing.

1.3. Intensive farming and crop production

In the field of crop breeding. The phenological and phenotypic characteristics of a collection of spring soft wheat, consisting of 300 recombinant inbred lines (RIL) and 180 local samples in the conditions of Northern and South-Eastern Kazakhstan, were carried out. Samples from Kazakhstan were genotyped for four specific genes associated with the quality traits of wheat: the content of yellow pigment in the grain, the proportion of amylose in starch, and the germination of seeds on the vine. In the field conditions of 2022 in the Almaty region, signs of the presence of three types of rust (leaf, yellow and stem), as well as signs of other diseases such as yellow spot and septoria, were found. As a result of genome-wide association analysis of RIL, a total of 283 quantitative trait loci (QTLs) associated with the components of yield, adaptability, and resistance to rust diseases were identified [272–273].

A collection has been formed based on the qualitative and quantitative characteristics of spring rapeseed from Russian and German selections, mutant lines of doubled haploids, as well as lines of doubled haploids of interspecific hybrids of rapeseed with rapeseed. Mutant doubled haploids were obtained from varieties and hybrids, collection samples. Based on the characteristics of cold and drought resistance and fatty acid composition, 31 lines were selected for testing in the field conditions of Northern Kazakhstan. As a result of field trials, lines of spring rape and its hybrids were selected that were quantitatively superior to control plants [274–275].

A collection of spring barley consisting of 177 samples of the RIL mapping population, 267 samples of American and 90 Kazakh selections was studied using 11 productivity indicators and 6 grain quality characteristics in the conditions of Almaty and Kostanay regions. 21 lines were identified that are promising for the selection of malting barley in the conditions of the north and southeast, including 2 lines that showed consistently low protein content (less than 12%) in both regions. As a result of GWAA, 50 marker-trait associations were discovered, which were combined into 30 QTLs with high statistical significance. A design of 45 KASP markers was carried out, of which, based on the results of validation, 12 KASP markers confirmed their association with traits of barley grain quality, 14 KASP markers with traits of adaptability, and 6 KASP markers with traits of barley productivity [276–280] .

In 4 barley varieties, 17 HvSAP genes encoding stress-associated proteins were identified, five of which - HvSAP5, HvSAP6, HvSAP11, HvSAP12 and HvSAP15 - are highly expressed in the leaves of barley plants in response to salt stress. The KATU-B30 SNP marker has been developed for the HvSAP12 gene. This SNP marker KATU-B30 is used in barley breeding to increase grain yield under abiotic stress conditions [275–281].

– purple (M. sativa L.) and variegated alfalfa (M. varia Mart.) of Kazakh and foreign selection from 18 countries of the world were studied in field and laboratory conditions [276–282]. The research was carried out on a collection seed plot on the main valuable selection characteristics - foliage, susceptibility to disease, productivity of green mass and seeds, chemical composition and nutritional value. Regarding plant height, the highest indicators were observed in varieties from Italy (k-5677), Russia (k-31885), Kazakhstan (k-6021), Estonia (k-38914), Ukraine (k-1721) and the USA (k-46451 The following samples had high foliage: the foliage of samples from Russia (k-45479), Kazakhstan (k-61324) and Italy (k-5677). Varieties from Kyrgyzstan (k-6238), Uzbekistan (k-21634) and Italy (k-5975) had complex resistance to fungal diseases (yellow leaf spot, brown leaf spot, leaf rust). The selected samples will be used in the further selection process to create new highly productive varieties adapted to the conditions of the south and southeast of Kazakhstan.

As a result of the research, genotype - dependent and organ-specific differential expression of genes involved in iron (Fe) homeostasis was identified in spring bread wheat genotypes that differ in the content of Fe and zinc (Zn) in the grain, the content of phytic acid and the bioavailability of metals. Two new mutant genotypes of spring bread wheat with target genes for Fe/Zn biofortification were identified, which expanded the understanding of the role of genes associated with metal homeostasis in the uptake, transport and redistribution of Fe/Zn in wheat grain [277–283]. Comprehensive studies of the genomic regions that determine the concentrations of micro- and macroelements in the grain of a group of 135 different wheat accessions were carried out through a genome-wide association study. The largest number of marker-element associations (MEAs) were identified for Mg (499), S (399), P (394), Ni (381), Cd (243), Ca (229), Mn (224), Zn (212), Sr (212), Cu (111), Rb (78), Fe (63), Mo (43), K (32) and Co (19). Additionally, MEAs associated with multiple elements, called pleiotropic SNPs, have been identified for Mg, P, Cd, Mn, and Zn on chromosomes 1B, 2B, and 6B. Fifty MEAs were validated using multisite KASIB trials at six sites over two years using 39 genotypes. MEA gene annotation identified putative candidate genes that potentially encode different types of proteins associated with disease, metal transport, and metabolism. The identified MEAs can be used in marker-assisted breeding to improve the concentration of nutrients in wheat grain [284,285].

Research has been carried out to develop and study a new, complex, highly effective organic fertilizer of humic nature for modern technologies, as well as its implementation to reduce the degradation of agricultural soils in arid and semi-arid regions of Kazakhstan and increase productivity. A universal plant growth and development stimulator EldORost was obtained from brown coal with the addition of a complex of amino acids, macro- and microelements, which had a positive effect on the productivity of potatoes and main vegetable crops, increasing productivity, while the increase in yield was: cabbage - 31.3%, cucumbers – 30.2%, tomatoes. – 34.7%, beets – 28.7%, carrots – 33.3%, potatoes – 36.8% [286]. The introduction of humate into base mixtures of industrial mineral fertilizers improves the growth, development and productivity of agricultural crops while reducing the consumption of mineral fertilizers by 30–50%.

1.2. Ensuring phytosanitary safety;

A method has been created for identifying phytopathogenic fungi that contaminate the germinal zone of wheat seeds using the Xtreme Chain Reaction [287]. A method for molecular genetic identification of phytopathogenic fungi using Xtreme Chain Reaction has been developed, which allows for accelerated detection of various types of phytopathogenic fungi [288].

Monitoring was carried out to determine the level of danger of pathogens of brown, yellow rust and leaf spot diseases on wheat crops in Almaty, Zhambyl, Turkestan, Kostanay and Akmola regions (2022 - 6678 hectares). A collection of 75 wheat samples was created that combine resistance to geographically distant Kazakhstan populations of brown, yellow rust and pyrenophorosis.

Pathovars in the population of black and basal bacteriosis have been identified and express methods for their detection have been developed. A multiplex PCR test system has been developed to detect polymorphism of tandem repeats in bacterial genomes to identify strains of pathogens of black and basal bacteriosis of wheat. Their population structure was determined using markers for tandem repeats.

A linkage map was constructed, quantitative trait loci (QTL) and closely linked molecular markers associated with wheat resistance to yellow rust were identified. QTLs associated with seedling resistance were identified on chromosome 4B, while QTLs found on chromosome 2B and 4D were mainly associated with resistance at the adult plant stage.

collection of tetraploid wheat varieties and lines was used to conduct a genome-wide association search (GWAS) using 16425 polymorphic SNP markers to identify QTL associated with leaf and stem rust resistance at the seedling and adult stages. QTL and DNA markers of durum wheat resistance to the most dangerous fungal diseases have been identified and new KASP markers have been developed. 10 promising lines of durum wheat resistant to fungal diseases have been identified.

Multiplex systems for detecting 20 viruses of agricultural crops (apple, grape, raspberry, potato, tomato, wheat) have been developed, which have been tested on positive controls for each virus and plant material. Virus detection systems have been introduced in the laboratory for the diagnosis of phytopathogens of the country's research institute: 1) « Grape virus detection system based on RT-PCR, raspberry virus detection system based on RT-PCR, apple virus detection system based on RT-PCR» in the laboratory of horticultural biotechnology, LLP Kazakh Research Institute of Horticulture and Vegetable Growing. Implementation period: start – 05/18/2022, end – 05/20/2022; 2) «System for detection of tomato brown wrinkling virus by real-time PCR» to the Almaty Zonal Quarantine Laboratory, a branch of the state institution « Republican Center for Plant Quarantine» . Implementation period: start – 05/02/2022, end – 05/20/2022.

Cryotherapy technology has been developed to eliminate viral and bacterial infections. A cryogenic collection of apical meristems of improved varieties of berry crops has been created. High-quality planting material of 5 commercial varieties of raspberries and 3 varieties of currants was obtained.

Monitoring of the main economically important potato viruses was carried out in seed and commercial farms in Kazakhstan. A distribution map of potato viruses Y, X, M, S, PLRV across Kazakhstan has been created.

Web databases of Science, Scopus [289–304].

2. *Processing and storage of agricultural products and raw materials;*

The influence of the degree of addition of meat-and-bone paste on the quality indicators of liver pate was studied, and the optimal percentage of adding meat-and-bone paste to the recipe for liver pate was determined. The chemical, mineral, and amino acid compositions of liver pate with the addition of meat and bone paste have been studied [305] .

A technology for canned meat from goat meat using plant materials has been developed. The nutritional and biological value of canned meat and vegetables with the addition of carrots (Daucus carota subsp. Sativus) was studied by partially replacing goat meat in the amount of 10%, 20% and 30% in the formulation [306].

3. *Technical support for the modernization of the agro-industrial complex;*

The influence of various methods of basic soil cultivation - chiseling with various types of chisel rippers and moldboard plowing - on the agro- and water-physical parameters of light chestnut soil was studied. Differences in soil density and moisture levels affected the development of corn plants. In variants with deep chisel processing, the accumulation of dry and wet plant biomass and the yield of corn grain were higher. Thus, basic tillage techniques make it possible to regulate the agro and water-physical state of the soil and have a significant impact on plant productivity. Based on the data obtained, for high-quality basic tillage of the soil, ensuring optimal indicators of its density, crumbling, reserves of total and available moisture in the soil, we can recommend the use of an experienced chisel ripper KR-2.4. The practical significance of the study lies in the identification of soil cultivation techniques that help increase moisture reserves in the soil and the yield of agricultural crops [307].

4. Sustainable development of rural areas

An innovative «Methodology (a set of algorithms and methodological approaches) for assessing the sustainable development of an administrative-territorial region based on the integral use of spatio-temporal data, as well as economic, social, environmental information» has been developed using the example of the Burabay district of the Akmola region [308].

Modeling and analysis of the efficiency of management of the energy and agro-industrial complex based on the introduction of digitalization to stimulate economic growth in Kazakhstan was carried out. Activities for the implementation of innovative projects in digital energy and smart agriculture are presented and summarized. The role of digital and electronic technologies in agriculture and the energy complex in promoting the economic growth of Kazakhstan is substantiated [309]. Econometric modeling was carried out to identify patterns and quantify the impact of electricity generation and digital farms on increasing agricultural production. The results of the regression model are substantiated using the EViews statistical application package. A medium-term econometric forecast for the development of the agricultural sector is presented, taking into account the introduction of digital farms [310].

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

The development and implementation of agrobiotechnologies, «green technologies», digital technologies play a decisive role for the sustainable development of agriculture in modern conditions.

Global climate change, reduction of land suitable for cultivation of crops, reduction of water resources, abiotic and biotic factors are major contributors to the growing threat to ensuring food security both in Kazakhstan and throughout the world [311]. Lack of food annually leads to global hunger for 10% of the world's population. According to FAO statistics, in 2021 in Central Asia, 4.9% and 15.3% of the population, respectively, faced severe and moderate hunger. In addition, due to the growing population in the next 25 years, it is necessary to increase the productivity of the agricultural sector by 60–100% [312].

To achieve food security, a global project « zero hunger and improved nutrition» has been launched, which requires fundamental changes in the field of crop and livestock production, and not their individual sections [312,313]. Cultivation of new varieties of cultivated plants with increased resistance to abiotic stress, introduction of innovative genetic technologies for breeding cultivated plants, conservation and fundamental study of the diversity of germplasm of wild plants, prevention of the spread of dangerous and invasive pathogens and plant pests, as well as the transition to « green technologies» with minimal use pesticides and fertilizers are the main priorities in the development of crop production in the world. Classical methods of crop production, introduced more than 15–20 years ago, are not effective and require enormous time and financial resources without a positive result.

Modern breeding and genetic programs in the world are based on the use of new effective tools and genomic technologies - full genome genotyping of agricultural crops, construction of high-resolution genetic maps associated with yield and determining grain quality, automation of the use of informative DNA markers in the breeding process [314–319].

CRISPR / Cas 9 technologies to quickly respond to abiotic and biotic stress will improve crops in a short time without loss of yield. Targeted genome editing CRISPR / Cas 9 has already made it possible to obtain resistant varieties to various biotic and abiotic stresses, as well as to increase productive qualities in 20 different crops [320,321].

At the present stage, selection is developing in a new aspect with the advent of phenomics. This allows breeders to accurately phenotype [1]numerous accessions, combined with NGS technology (next generation sequencing) breeders will be able to link many more phenotypes to corresponding genotypes. In recent years, the field of phenomics has applied advanced computational methods such as machine learning, deep learning and artificial intelligence in combination with high-throughput phenotyping to predict the performance of breeding populations of various crops. These methods are inherently interdisciplinary approaches to data analysis, which are usually robust when working with large volumes of data [322]. Maintaining crop yields in a changing climate requires advances in bioinformatics to use data from large phenomics and genomics datasets to translate research findings into climate-adapted crops in the field [323]. Climate change has a major impact on the environment and crop production today and in the future. The concept of environmental typing is proposed as a third « typing» technology to accompany phenotyping and genotyping to decipher environmental influences on crop breeding. Ecotyping plays a key role in crop modeling and phenotype prediction due to its powerful components including genotype-environment interaction (GEI), environmental signals, responsive genes, biotic and abiotic stresses, and integrative phenotyping. New areas of research based on genome-environment associations are emerging, which integrate environmental climate data with evolutionary genomics [319–324]. The authors advocate for the community to begin collecting genome-wide estimated adaptive values (GEAVs) for genomic prediction (GP) and multivariate machine learning models to account for polygenic evolutionary adaptation. An integrated selection scheme with prediction of the genomic environment using integrated multi-omics information, big data technology and artificial intelligence is proposed [320–325].

[1] Plant phenotyping is a procedure for assessing the phenotype of a plant based on its size, shape, physiological and biochemical characteristics under specific environmental conditions and genome activity.

As an example in the above-mentioned promising direction of cooperation with international scientific organizations, a technical project of the LLP Kazakh Research Institute of Agriculture and Plant Growing together with the Ionomics Center of the University of Nottingham (UK) is presented within the framework of the Horizon 2020 program, the European Plant Phenotyping Platform (European Plant). Phenotyping Platform) to study the ionomics of spring wheat grain. The Center for Ionomics focuses on providing researchers with large-scale phenotyping methods that underpin deciphering gene function and gene regulatory networks (https://www.nottingham.ac.uk/research/beacons-of-excellence/future-food/tools – and-resources/platforms/ionomics/index.aspx). As part of a project based on the ionomic phenotyping platform of the University of Nottingham (UK) of the European Plant Phenotyping Network, a study was carried out to determine the concentration of 20 elements, including macro- and microelements, heavy metals in more than 2000 wheat samples [321–326].

The main result of this study is the reliable validity of the high food safety of spring wheat grain produced in Kazakhstan and Omsk (Western Siberia, Russia). Despite the presence of industry in the Aktobe, East Kazakhstan and Omsk regions, the concentration of toxic metals (As, Cd, Cr, Li, Pb) was either below the limit of quantification or was present in insignificant quantities that do not pose a threat to human health. The concentration of essential microelements is similar to wheat grain from other countries and continents, with the exception of Zn. The concentration of this important element exceeded 50 μg/g in Omsk and Eastern Kazakhstan, which is higher than the values provided by the Harvest Plus biofortification program. Even with the loss of zinc during milling, this grain will be beneficial to human health, offering new marketing opportunities.

For plant science to provide solutions to major problems in agriculture and the environment, understanding the fundamental processes affecting crop productivity or ecosystem functioning must be a priority. New research demonstrates the unique power of phenomics for understanding plant physiology by statistically correlating measured properties. Functional phenomics is proposed as a field of research that uses high-throughput phenotyping to generate knowledge about plant function at the physiological level and works synergistically with advanced genetics.

Another area of application of phenomics in the applied aspect is yield forecasting.

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

In highly developed foreign countries in previous decades, an interdisciplinarity approach has been successfully implemented in the organization of scientific research, which involves simultaneous solution of the problem at three levels: 1) methodological - formulation of the subject of research, reflection of the object from such a position that it becomes possible to use the means of various disciplines for study, and the results obtained the results contributed to clarifying and improving the initial data; 2) organizational – creating a communication network and ensuring the interaction of researchers to participate in obtaining and discussing results, attracting representatives of related disciplines; 3) informational – ensuring the translation of applied results of interdisciplinary research into the plane of making practical decisions, transferring one's own scientific results for examination in the system of disciplinary knowledge.

With the implementation of this approach, a transformation began from scientific schools to the formation of multidisciplinary scientific groups.

Recently, the transition from an interdisciplinary to a transdisciplinary approach to organizing scientific research has been actively discussed. Interdisciplinarity, according to the scientific community, implies the simple « borrowing» of techniques and methods from other fields of science, while transdisciplinarity implies a «functional synthesis of methodologies», the creation of completely new research concepts on their basis.

An example is the organization of scientific research within the framework of the Strategic Initiative for Designing Future Wheat (Designing Future Wheat Institute Strategic Program) is a fully integrated, dedicated national wheat research program involving more than 25 teams of scientists from Rothamsted Research, the John Innes Center and the Earlham Institute, as well as the National Institute of Agricultural Botany, the European Bioinformatics Institute, the Universities of Cambridge, Bristol and Nottingham. This strategic program includes four work packages (subprograms) and is funded by the UK Government Biotechnology and Biological Sciences Research Council (BBSRC). As part of the strategic program for designing future wheat, a comprehensive inter and transdisciplinary approach is being implemented to organize scientific research from the fundamental principles of preselection in the aspect of identifying traits of resistance to biotic and abiotic stress factors, productivity in complex at the genomic and phenomic level, to applied application in the synthesis and production of initial forms of material to create new lines and varieties of wheat. It is important to note that in the UK and in many leading foreign countries, private commercial enterprises are creating new lines and varieties; they are also developing varietal agricultural technology. At all stages of scientific research within the work packages of the above strategic program, breeders of private commercial enterprises are actively involved. These same enterprises—producers of original varieties—co-finance strategic programs and projects and are co-customers for research results [327–328].

Priority X – «National Security and Defense»

1. Review and analysis of the achievements of Kazakhstani science (the most significant results of the scientific and (or) scientific and technical sphere, implemented developments

Considering that the scientific results of research in the field of military sciences are often information of limited distribution or are classified, the publication activity of military scientists is limited mainly to domestic publications.

In the context of the emergence of new risks and threats, one of the main priorities for the development of the Republic of Kazakhstan is security, which is confirmed by doctrinal guidelines. The set of measures to ensure the country's security and defense includes the development of the military-industrial complex and its scientific and technological component as a key direction [329].

Priority in the development of science should be such trends as the preparation of breakthrough projects in the field of scientific and technological development in order to ensure the competitiveness of the country's economy and its defense capability; development and implementation of commercial technologies that meet international standards and requirements; participation in international scientific and technological cooperation; training of scientific personnel in priority areas based on the implementation of scientific projects together with reputable world scientific centers.

Scientific and technical production centers in Kazakhstan are mainly concentrated in cities such as Astana, Almaty, Karaganda, and Ust-Kamenogorsk. This location makes it possible to create regional scientific, production and functional networks that expand the range of opportunities for the production of scientific and intellectual products, improving the national security system of Kazakhstan, its defense, aerospace and electronic industries, developing artificial intelligence and information technologies.

The implementation of scientific research in the field of security and defense is carried out by scientific, educational and scientific-technological organizations and divisions that are part of the system of law enforcement agencies and the military-industrial complex of the Republic of Kazakhstan (DIC RK).

Based on statistical data for 2020–2022, the following main areas of military scientific activity in the interests of the defense industry and law enforcement agencies are identified: scientific research work (R&D); experimental design work (R&D); development of regulatory legal acts (RLA); development of regulatory and technical documents (including military standards (MS); sociological research (SR); analytical research (AR); scientific and technical examination (STE); marketing research (MR); dissertation research for the degree of Doctor of Philosophy (PhD).

According to the focus of research and development, R&D is divided into: R&D carried out in the interests of enterprises of the defense industry of the Republic of Kazakhstan; R&D carried out in the interests of defense industry enterprises of the Republic of Kazakhstan; Research carried out in the interests of the security forces of the Republic of Kazakhstan; R&D carried out in the interests of the security forces of the Republic of Kazakhstan (fig. 3.44).

The conditions and trends in the scientific and technological development of the most successful states indicate that one of the fundamental foundations for the development, production and improvement of weapons of the future is the electronics industry. This is explained by the fact that without its high-tech products of a wide range, the use of weapons of the future is simply impossible, be it space and aviation technology, communication systems, UAVs, UUVs, UGV robotics, exoskeletons, air defense systems, armored vehicles and other types of weapons and equipment.

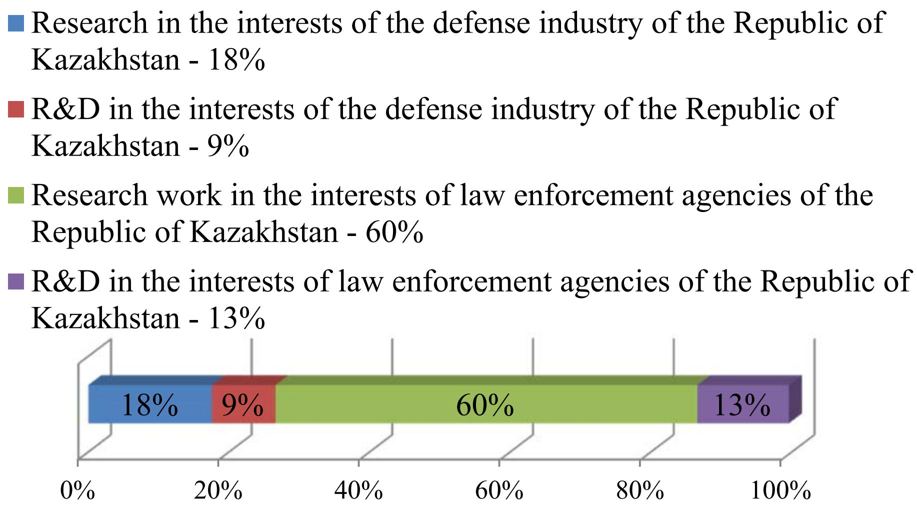


Figure 3.44. Correlation of types of scientific and technological activities in 2020–2022

Information and telecommunication technologies in Kazakhstan are directly dependent on foreign electronics manufacturers. By 2022, its production in Kazakhstan has not yet been established; the development of the national electronics industry has just begun. Therefore, in activities to develop the domestic defense-industrial complex and its scientific and technological component, it is advisable and logical to use scientific and technological developments available in other industries for the production of weapons and military equipment.

2. Review and analysis of global trends in science, examples of cooperation between domestic scientists and foreign scientists and work performed under an agreement with international scientific organizations

The factor of global instability forces the leadership of many countries to take measures to ensure their security, which is illustrated by the increase in military spending of China, Russia, Ukraine, the USA, NATO and other countries [330, 331]. A factor in increasing the military power of advanced states was and is the development of scientific research and development (R&D) both in the military sphere and in the production of dual-use products.

United States of America. The organizational and technical conditions in which the US scientific and technological sphere is developing are clearly visible in the example of the American structures DARPA, NASA, RAND [332]. The goals, objectives and functions of the state as the main factor in the promotion and financing of military R&DW and dual-use R&DW in the United States are implemented through a multi-level and extensive state structure, a network of private scientific, technological and manufacturing firms and companies, a scientific and educational system, which includes universities, «think tanks» and scientific and technological laboratories of various profiles. The main customers for their scientific and technological products (R&DW and R&D) are US government agencies.

European Union. The lack of coordination of defense, and, in particular, military-technical policy has led to the use by EU countries of almost 180 types of weapons and equipment in their armies. Here it is appropriate to point out for comparison that the leader of NATO, the United States, has no more than 30 names. To rectify this situation, the European Defense Fund (EDF) was created, which is intended mainly to coordinate and complement the investments of EU member states in defense developments in the interests of their armies and indirectly to achieve interoperability of command and control systems and weapons [331, 333, 334].

Federal Republic of Germany. The rationale for the national defense industry and the scientific and technological sphere in Germany was much less clear, since nowhere else than in the security field did Germany have to act more cautiously due to its history. It must be emphasized that out of 100 companies producing weapons, 47 are American and only 7 are German. Although individual firms contracted by the German Ministry of Defense showed a relatively low share of arms production in total sales, the opposite was true for the other type of concentration index. The 10 largest arms manufacturers in Germany received about 68% of all contracts for the purchase of their products [333, 335, 336, 337].

The Republic of Korea. In the Republic of Korea, the administration of the Defense Acquisition Fund (DAP) was formed, the purpose of which was to increase the efficiency of project management in the field of improving defense capability, purchasing ammunition and scientific and technological development of the defense industry of the Republic of Korea. The DAP implements two main directions: financing joint research in the field of scientific and technological innovative defense technologies (electronics, metacomposite materials, encrypted software and robotics); examination and acquisition of weapons and military equipment. The main sources of funding for FZ are the state budget of the Republic of Korea and offset transactions [335, 338, 339, 340].

Turkish Republic. Turkey's state policy in the defense industry is aimed at developing the professional level of personnel in the armed forces and defense industry. To this end, in recent years, training of Turkish military personnel in new military technologies in universities in the USA and Europe has been actively stimulated. The main defense industrial institutes were created to meet the needs of the Turkish Armed Forces. The success of this effort is particularly evident in the nation's naval, air and land platforms, including artillery, missiles, national sensors, software and logistics, effective artillery, C4I and other systems. By 2022, Turkey has joined the list of the world's largest small arms exporters, led by the United States, China, the Czech Republic and Russia. The TR defense industry has an extensive research and development program, the main sponsor of which is the Scientific and Technological Research Council of Turkey TÜBİTAK [330,331, 341].

Russian Federation. The Advanced Research Fund (APF) has been created in the Russian Federation, which is intended to establish a strong connection between fundamental science, applied research and industry in the interests of the Russian defense industry. The FARP is, if not an exact copy, then a smaller analogue of the American DARPA Agency, with the difference that Russia relies on the military-industrial complex as a catalyst for a scientific and technological breakthrough [330, 331, 342, 343].

Thus, it is necessary to highlight four main trends in the promising development of methods and technologies: high-speed means, digital production, promising unmanned technologies, smart weapons.

The analysis shows that the most powerful countries in terms of innovation, technology and economics strive to have the most powerful armies, and military budgets traditionally play a key role in their economies. In the modern world, the American socio-economic system is still the leader, with which only the EU and China will be able to compete by 2022 [330,331,344,345].

3. Analysis of achievements and development trends of leading scientific schools in Kazakhstan and highly developed foreign countries

An analysis of open sources of scientific activity of military organizations shows that in this area military scientific schools have developed in the areas of «Military Art», «Weapons and Military Equipment»», «Military History», «Law Enforcement», « Jurisprudence».

In the interests of the defense industry of the Republic of Kazakhstan, research work was organized at the LLP R&D – «Center of Kazakhstan Engineering». During the period from 2020 to 2022, the main scientific research of the Center was carried out in the field of creating special tracked vehicles, developing a robotic complex using artificial intelligence, a software and tool complex for supporting strategic decisions, implementing logistics systems, developing protective surface coatings for protection from environmental factors, logistics support for troops and others.

During its existence (since 2015), LLP «Kazakhstan Paramount Engineering» has produced and supplied to the Army and law enforcement agencies more than 150 units of modern armored combat wheeled vehicles «Arlan», «Alan» and «Barys» . In addition to production, the company is engaged in research and development of new types of military equipment and weapons. Since 2020, the development of the first Kazakh armored wheeled vehicle, Alan-2, has been underway. In 2021, the company completed research work to develop a prototype of an artillery fire control system. The company localizes the production of electrical and pneumatic systems and weapons components.

The Republican public association « Academy of Military Sciences», created to unite military scientists of the power bloc in the interests of developing military science of the Republic of Kazakhstan, is an accredited scientific organization that participates in competitions for grants and program-targeted funding. In 2020, the academy completed scientific projects in the interests of the Border Service of the National Security Committee of the Republic of Kazakhstan.

In order to produce scientific and technological products for making management decisions in the field of defense and national security, research is carried out by the JSC Center for Military-Strategic Research, subordinate to the

Ministry of Defense. Some of the Center's research includes analyzes of the global value chain and suppliers of technological solutions for organizing the production of military and dual-use products in Kazakhstan in 2020, and in 2021: an information and analytical review «Transboundary water use during integration processes in Central Asia (problems and solutions)» , scientific research «Transformation of the security sphere of Central Asia in the Afghan direction» (through the Chinese Embassy in the Republic of Kazakhstan) and others.

Scientific research in the military field is also carried out by higher military educational institutions of the Ministry of Defense: National Defense University named after the First President of the Republic of Kazakhstan - Elbasy (as part of a military research center), Military Engineering Institute of Radio Electronics and Communications, military institutes of the Ground Forces, Air Defense Forces (table 3.24).

Table 3.24. Information on the availability of scientists and academic degrees of universities of the Ministry of Defense of the Republic of Kazakhstan

University	Ph.D	PhD	d.f. (PhD)	Master
National Defense University	6	25	48	112
Military Institute of the Ground Forces	1	7	1	98
Military Institute of Air Defense Forces	–	5	1	22
Military Engineering Institute of Radio Electronics and Communications	3	8	6	136
Total	**10**	**45**	**56**	**368**

In 2020–2022, scientific research was carried out in these universities in the following areas. By 2020, 13 grant projects and 3 program-targeted financing programs totaling 1.3 billion tenge were completed [346].

One of the directions of this research was the analysis and acquisition of new knowledge on the tactics of the Special Operations Forces. A separate project was devoted to the theory and practice of territorial defense and the mechanisms of its integration with local governments. The purpose of another study was to develop recommendations for improving the work of command personnel when organizing combat operations in urban areas. Research on the creation and development of reconnaissance and fire (strike) complexes was carried out within the framework of the following project.

A study was conducted on the conversion of anti-aircraft guided missiles of second-generation anti-aircraft missile systems into missile targets, the implementation of the results of which can provide a significant economic effect for the Republic of Kazakhstan.

In the course of scientific research on ensuring the safety of maritime objects and the creation of surface unmanned boats, a draft Concept for the protection and defense of maritime strategic objects by robotic systems, a Technical Assignment for the implementation of R&D for the development of an unmanned boat and an autonomous uninhabited underwater vehicle were developed.

As part of program-targeted financing, the development and testing of the Shagala reconnaissance unmanned aerial vehicle with control and protection software and a set of design documentation was carried out. In 2022, based on a licensing agreement, « LLP R&D Center of Kazakhstan Engineering» received a grant for the commercialization of the results of scientific and scientific-technical activities for the production of domestically developed unmanned aerial systems (UAS).

Another scientific program was aimed at developing a special geoinformation platform in the interests of defense and security of the Republic of Kazakhstan for modern topographic support systems for military command and control bodies with automated workstations, which allows increasing the level of automation of decision-making processes by command and control bodies and reducing labor costs and time for making decisions on combat actions.

In 2021, research was carried out on the development of a mass spectrometer for non-destructive diagnostics of materials used in the aerospace field, on the development of a computer model of a solar battery based on layered nanostructures.

In 2022, research began on the development of closed-loop technology for processing and visualizing geospatial data in order to improve the efficiency of decision-making by military command and control authorities [347]. The implementation of the program will create the basis for the introduction of innovative technologies into the geographic information support system for troops, including virtual reality (VR), which will allow the user to immerse themselves in a virtual environment with an immersive effect.

Research was carried out to create a sample of a single-channel tropospheric station, within the framework of which the possibility of creating new low-cost communications equipment capable of providing radio communications in « dead zones» under different climatic conditions was proven; the possibility of creating domestic tropospheric radio communication stations with high export potential has been proven.

Other work concerned the development of the scientific and theoretical foundations of civil defense of the Republic of Kazakhstan, taking into account new threats and challenges [348].

For 2020–2022 documents of protection (patents) for the hydrogen generator were obtained; UAV launch device; armored technical reconnaissance vehicle; frame structure of a box-beam type of an armored vehicle; mobile chamber for applying anti-corrosion coatings; mobile psychological assistance center; field portable diagnostic complex for a family of armored wheeled vehicles and others.

Copyright certificates were obtained for the developed information support for complex organizational and technical control systems for military vehicles; methodology for assessing the level of moral and psychological state of personnel; marching calculator for calculating marching indicators of units and subunits; methodology for organizing a surveillance system, checkpoints and patrols during a peacekeeping operation; methodology for assessing the effectiveness of the use of troops in combat operations; special software of the software and hardware complex and others.

In the interests of training scientific and scientific-pedagogical personnel for the Armed Forces, other troops and military formations of the Republic of Kazakhstan, doctoral studies operate at the National Defense University of the Ministry of Defense of the Republic of Kazakhstan, the Academy of Law Enforcement Agencies under the General Prosecutor's Office of the Republic of Kazakhstan, and the Academy of the Border Service of the National Security Committee of the Republic of Kazakhstan. According to official data, during 2020–2022, 24 dissertations were defended through the Ministry of Defense for the degree of Doctor of Philosophy (PhD), and 9 dissertations were defended through the Prosecutor General’s Office.

Within the framework of the scientific school in the field of weapons and military equipment, 7 dissertations were defended during the reporting period, including on the development of mobile equipment for the production of biodiesel fuel, on the development of a hardware and software complex for radio and acoustic tomography, on the development of a power plant using alternative energy sources , on the development of a technology for preparing worn surfaces of parts for restoration by supersonic spraying, on the development of a technology for diagnosing anti-aircraft artillery barrels and others.

Within the framework of the scientific school in the field of military art, 7 dissertations were defended, including on the issues of combat tactical groups, special operations forces, the use of territorial troops, moral and psychological support, and others.

In the field of military history, the scientific school is represented by the defense of 10 dissertations, including on the military-patriotic education of youth, on the combat activities of rebel and regular formations against Soviet power in Central Asia, on the creation of the Central Asian Military District and its activities, on the experience of participation of the Armed Forces of the Republic of Kazakhstan in peacekeeping activities and others.

The scientific school on law enforcement is represented by the defense of 5 dissertations, including on the problems of implementing international standards for combating transnational organized crime in criminal legislation, on the problems of combating corruption in internal affairs bodies, on the problems of prosecutorial supervision over the application of land legislation, and others.

The scientific school of jurisprudence is represented by the defense of 4 dissertations, including on the problems of investigating crimes in the monetary sphere, on the organizational and legal aspects of the investigation and prevention of non-fulfillment and improper fulfillment of responsibilities for the education of minors, on methods for investigating fraudulent actions in the field of real estate, and others.

4. ANALYSIS OF THE STATE OF SCIENTIFIC POTENTIAL (qualitative composition of scientific organizations and higher educational institutions, autonomous educational organizations engaged in science, quality of training of domestic scientific personnel, attraction of foreign scientists, equipping scientific laboratories with modern equipment for conducting scientific research)

Two input indicators are used for statistical survey of scientific and scientific-technical research and experimental development in the state statistics: the number of personnel engaged in scientific research and development and expenditures on R&D. The number of organizations that participated in the performance of scientific works, is formed based on the survey results. Data on these indicators can be presented by regions, economic sectors, types and forms of organization ownership. In addition, personnel are grouped by scientific categories, by age, and by branches of science.

Network of scientific organizations. According to state statistics, in the Republic of Kazakhstan, in 2022, **414** organizations were engaged in scientific research and development. This is 24 units less than in the previous year. The number of organizations remained unchanged in Akmola, West Kazakhstan, Zhambyl, Karaganda regions and Astana city; in the rest, except for newly formed ones, it decreased (table 4.25).

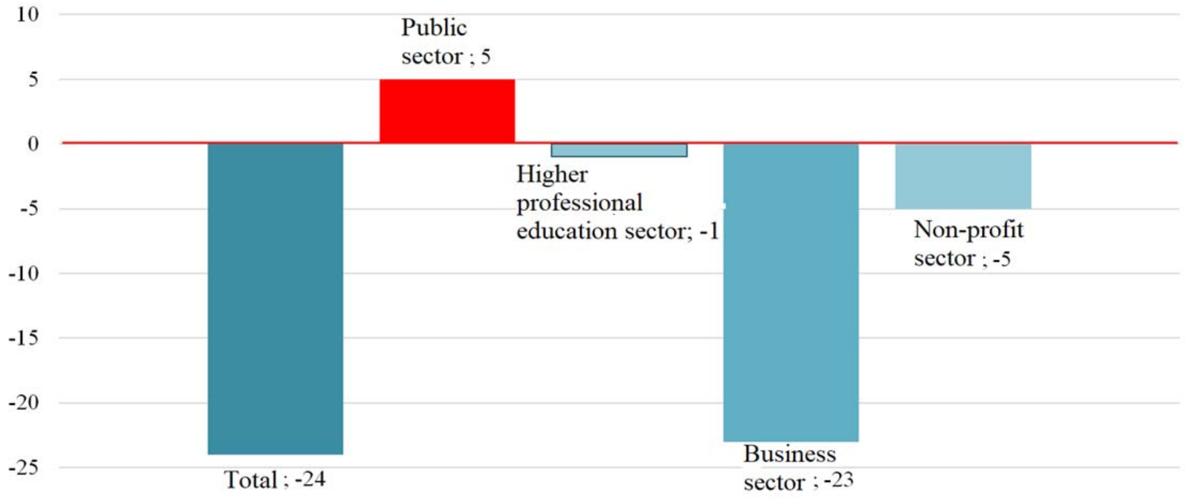
Table 4.25. Number of organizations performing R&D

units

Region	2020	2021	2022	Increase/decrease (–) relative to 2021, units
The Republic of Kazakhstan	396	438	414	–24
Abay region		0	10	10
Akmola	12	10	10	0
Aktobe	15	15	13	–2
Almaty	9	10	8	–2
Atyrau	10	10	8	–2
West Kazakhstan	10	9	9	0
Zhambyl	9	9	9	0
Zhetisu region		0	2	2
Karaganda	29	38	38	0
Kostanay	13	15	14	-1
Kyzylorda	7	10	7	–3
Mangystau	6	7	5	–2
Pavlodar	10	9	6	–3
North Kazakhstan	5	8	7	-1
Turkestan	8	9	8	-1
Ulytau region		0	1	1
East Kazakhstan	thirty	37	25	-12
Astana city	76	90	90	0
Almaty city	135	139	132	–7
Shymkent city	12	13	12	-1

According to the Bureau of National Statistics ASPR RK

The decrease in the total number of organizations conducting scientific research led to a decrease in all sectors except the government (fig. 4.26). It noted an increase in the number of organizations by 5 units. Despite this, business sector organizations predominate in number and structurally. They account for more than 43% of all organizations operating in the field of research activities (table 4.26).



According to the Bureau of National Statistics ASPR RK

Figure 4.45. Change in the number of organizations by sector of activity in 2022 relative to 2021, units

Table 4.26 Number of organizations performing R&D, by sector of activity

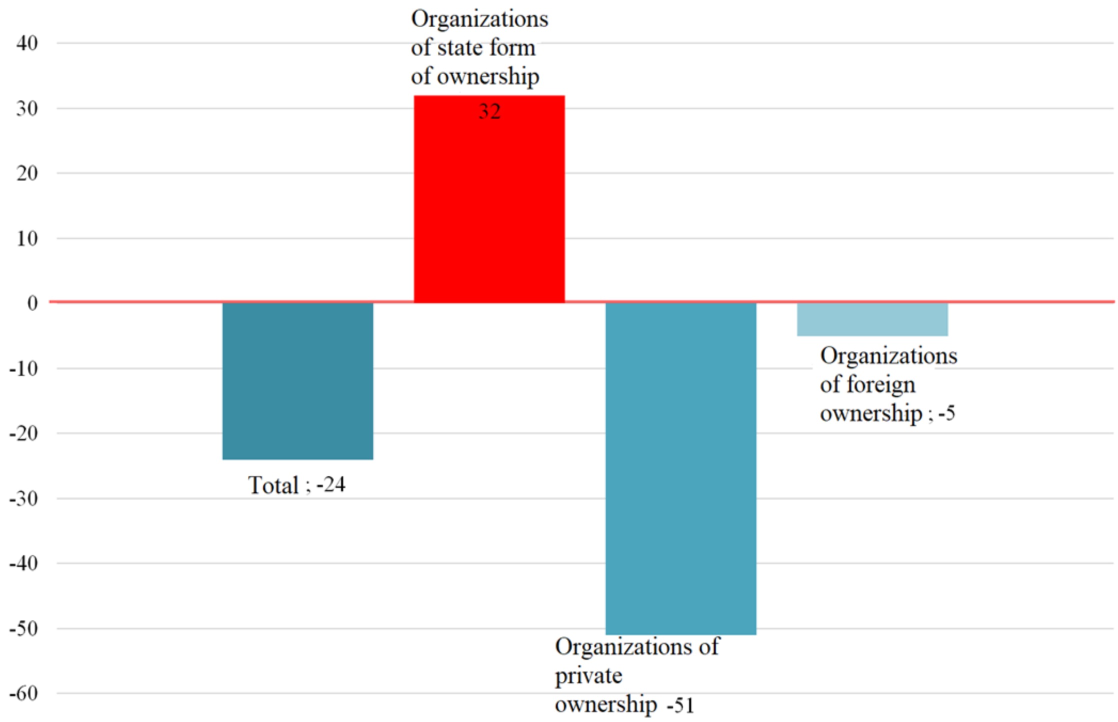
units

Indicators	2019	2020	2021	2022	Structure of organizations, %
Total	**386**	**396**	**438**	**414**	**100**
including					
government sector	100	93	101	106	25.6
sector of higher professional education	92	99	95	94	22.7
business sector	158	167	202	179	43.2
non-profit sector	36	37	40	35	8.5

According to the Bureau of National Statistics ASPR RK

The structure of organizations that carried out R&D is dominated by ***privately owned organizations.*** And, despite a significant decrease in their number (-51 organizations) (fig. 4.45), their share accounts for about 69%. The share of organizations with state ownership increased by 8,8 percentage points or by 32 organizations. The share of foreign-owned organizations is 3.1% (table 4. 27).

Personnel potential. In 2022, *the number of scientific workers* as a whole numbered ***22 456*** people. This number includes skilled and unskilled workers, secretarial and clerical personnel, as well as specialists whose activities are related to R&D services.



According to the Bureau of National Statistics ASPR RK

Figure 4.46. Change in the number of organizations by type of ownership of organizations in 2022 relative to 2021, units

Table 4.27. Organizations by type of ownership

units

Index	2020	2021	2022	Structure, %
Total	**396**	**438**	**414**	**100**
State	78	84	116	28.0
Private	305	336	285	68.8
Foreign	13	18	13	3.1

According to the Bureau of National Statistics ASPR RK

The number of research specialists, i.e., employees professionally engaged in R&D and directly involved in creating new knowledge, including administrative and managerial personnel (including heads of scientific organizations and units performing scientific research and development), amounted to 18014 persons (table 4.46).

The measures taken by the state to develop science have yielded results. Despite the reduction in the network of organizations, the total number and number of research specialists has increased. The general staff increased by 839 people, or 3,9%, research specialists – increased by 922 people, or 5,4%. This contributed to an increase in the average occupancy of organizations, which should improve the quality of research and its effectiveness. On average in the republic in 2022, there were 54 people per scientific organization, which is 5 people more than in 2021.

In 8 out of 20 regions of the Republic of Kazakhstan, there was a reduction of general staff/personnel, and research specialists in 7.

Table 4.28. Number of personnel engaged in research and development by region of the country

human

	Number of personnel, total				Research specialists			
Region	2020	2021	2022	Increase/ decrease (–)	2020	2021	2022	Increase/ decrease (–)
The Republic of Kazakhstan	22 665	21,617	22 456	839	18 228	17,092	18,014	922
Abay region			1,042	–			798	–
Akmola	733	782	748	–34	465	523	477	–46
Aktobe	431	381	420	39	384	335	380	45
Almaty	798	697	330	–367	545	501	179	–322
Atyrau	476	427	111	–316	468	417	104	–313
West Kazakhstan	517	441	417	–24	491	430	403	–27
Zhambyl	349	393	407	14	308	351	352	1
Zhetisu region			308	–			305	–
Karaganda	1 168	1 134	1 272	138	894	910	980	70
Kostanay	635	570	484	–86	503	442	411	–31
Kyzylorda	260	239	293	54	174	165	218	53
Mangystau	685	650	661	eleven	615	590	601	eleven
Pavlodar	514	447	477	thirty	427	363	368	5
North Kazakhstan	120	163	161	–2	102	114	118	4
Turkestan	251	245	239	–6	230	209	204	-5
Ulytau region			2	–			2	–
East Kazakhstan	1 804	1 902	1,004	–898	1 297	1 355	691	–664
Astana	3,942	3,894	4 265	371	3 187	3 154	3,554	400
Almaty city	9 299	8 730	9 191	461	7,502	6,763	7 280	517
Shymkent	683	522	624	102	636	470	589	119

According to the Bureau of National Statistics ASPR RK

However, it should be borne in mind that the decrease in the number of workers in the Almaty region by 367 people or 52,7%, the East Kazakhstan region - by 898 people or 47.2%, and the Karaganda region - by 138 people or 12,2% is due to the fact that new areas with significant scientific potential were formed from these regions.

So, for example, Zhetysu region was formed from the Almaty region with its center - the city of Taldykorgan, in which 308 people were engaged in scientific research.

The Abay region was formed from the East Kazakhstan region, on the territory of which the largest scientific centers are located in the city of Kurchatov (507 people) and Semey city (535 people).

In Aktobe, Zhambyl, Karaganda, Kyzylorda, Mangystau and Pavlodar regions, as well as in the cities of Astana, Almaty and Shymkent, both the total number of personnel and the number of research specialists increased. In the North Kazakhstan region, there were minor changes in the total number of personnel and the number of research specialists.

An indicator characterizing the involvement of labor resources in scientific research and development is ***the number of researchers per 10 thousand people employed in the economy***.

In the republic as a whole in 2022, this figure remained at the level of the previous year - 25 people per 10 thousand employees, at the same time, the number of research specialists increased and amounted to 20,1 people .

For comparison, according to the UNESCO Institute for Statistics, in Germany, this figure averages 233 people, in Japan – 180, in China – 81 people per 10 thousand people employed in the country's economy.

As in the previous year, the involvement of personnel, including research specialists, in research activity was higher than average republican indicators only in four regions: in Almaty and Astana cities, Abay and East Kazakhstan regions (table 4.29).

Table 4.29. Number of personnel engaged in research and development in 2022, calculated per 10 thousand people employed in the economy

human

	Personnel engaged in R&D, per 10 thousand people employed in the economy	Research specialists per 10 thousand people employed in the economy	Employed population*, thousand people
The Republic of Kazakhstan	**25.0**	**20.1**	**8971.5**
Abay region	36.3	27.8	287.1
Akmola	17.8	11.3	421.4
Aktobe	9.9	8.9	424.7
Almaty	4.7	2.6	697.7
Atyrau	3.4	3.2	326.7
West Kazakhstan	12.6	12.2	330.9
Zhambyl	7.5	6.5	539.5
Zhetisu region	9.6	9.5	319.7
Karaganda	23.8	18.3	534.8
Kostanay	10.7	9.1	453.8
Kyzylorda	8.9	6.6	330.1
Mangystau	19.9	18.1	332.7
Pavlodar	12.4	9.6	384.2
North Kazakhstan	5.8	4.2	279.1
Turkestan	3.0	2.6	792.2
Ulytau region	0.2	0.2	100.9
East Kazakhstan	27.4	18.9	366.5
Astana	68.2	56.8	625.5
Almaty city	92.1	72.9	998,
Shymkent	14.6	13.8	426.1

Calculated according to the Bureau of National Statistics ASPR RK

* Source of information: Main indicators of the labor market by region of the Republic of Kazakhstan 2001–2022.

When assessing human resources, representative indicators include full-time equivalent and worker mobility rates.

For reference. Full-time equivalent (FTE) is an indicator that reflects the time actually spent by personnel on R&D and demonstrates the effectiveness of the use of human resources.

An FTE of 0,7 indicates that only 70% of work time is spent on R&D. When recalculating the number of full-time workers, it turns out that in 2022, 13,7 thousand people were actually directly involved in research activities. If, according to statistics, there are 18,0 thousand specialists employed in research, then the difference is more than 4,3 thousand people.

11 out of 20 regions have FTEs below the national average. In Shymkent city, as well as in West Kazakhstan, Kostanay, Atyrau, Pavlodar, Karaganda and North Kazakhstan regions, the FTE was either less than 0,5 or slightly higher than this figure. It turns out that in these regions, during the year, each researcher spent no more than 4 hours daily on scientific activities (table 4.30).

Table 4.30. Full-time equivalent of research specialists

Region	2020	2021	2022
The Republic of Kazakhstan	0.73	0.72	0.76
Abay region			1
Akmola	0.84	0.82	0.85
Aktobe	0.52	0.54	0.59
Almaty	0.78	0.73	0.91
Atyrau	0.95	0.85	0.5
West Kazakhstan	0.54	0.41	0.43
Zhambyl	0.81	0.82	0.83
Zhetisu region			1
Karaganda	0.74	0.71	0.53
Kostanay	0.47	0.49	0.47
Kyzylorda	0.77	0.83	0.72
Mangystau	1	1	1
Pavlodar	0.66	0.53	0.52
North Kazakhstan	0.54	0.62	0.57
Turkestan	0.5	0.89	0.94
Ulytau region			1
East Kazakhstan	0.65	0.65	0.75
Astana	0.71	0.71	0.74
Almaty city	0.8	0.81	0.9
Shymkent	0.39	0.38	0.4

According to the Bureau of National Statistics ASPR RK

Another indicator is *labour mobility* (hiring, dismissal or transfer to another workplace, etc.).

After completing higher or postgraduate education in 2022, 716 people entered the scientific field, of which 69 were PhDs, 65 were candidates of science, 14 were doctors of science and 394 were masters, 1643 were from other scientific organizations. The bulk of those admitted, 2921 people, came to the scientific field from other places unrelated to scientific activities. In total, 5280 people were accepted into research activities. At the same time, in 2022, the number of employees who left for various reasons amounted to 3722 people, of which 2161 people left at their own request, 214 people left due to staff reduction, and 1347 people left for other reasons. Data indicates that almost a third of the scientific workforce was renewed in 2022.

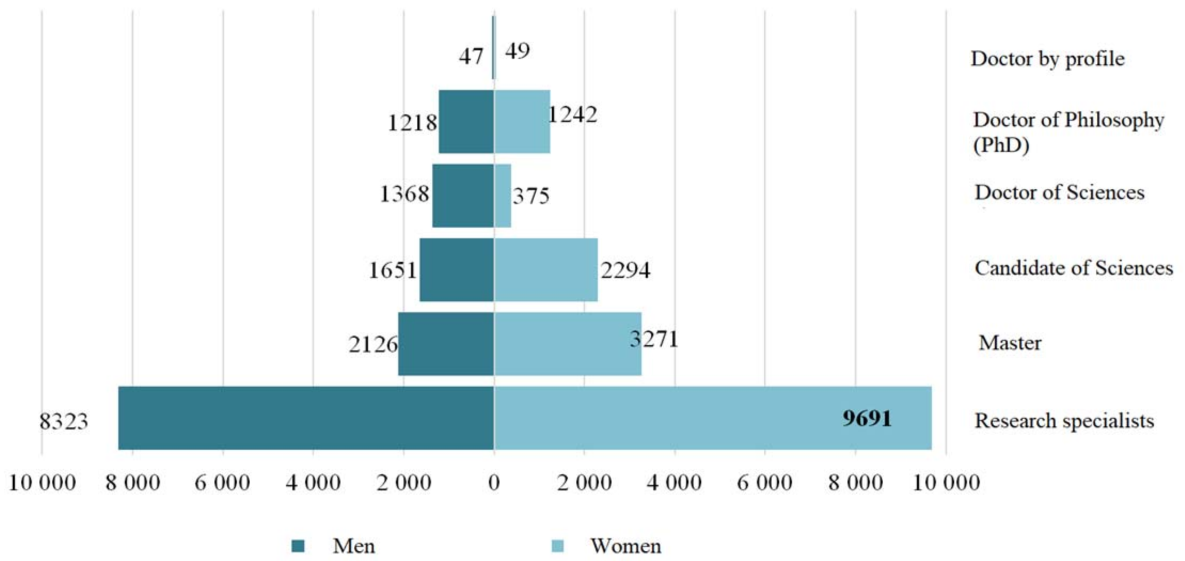
High rates of mobility negatively impact the quality and productivity of research.

Research specialists directly involved in R&D make up about 80% of the total number of personnel, i.e. They also perform most of the technical and support work. For comparison, in China this figure is 44%, in Germany – 61%, in the UK – 67%. In 2021, the average for OECD countries was 66% [349].

According to the UNESCO Institute for Statistics, women account for about 40% of research professionals in the world as a whole. Kazakhstan is one of the few countries where women outnumber men and is one of the three countries in the world ranking with the leading number of women in science.

In 2022, as in previous years, more than 50% of masters, candidates of science and doctors of philosophy were women (fig. 4.47).

Human



According to the Bureau of National Statistics ASPR RK

Figure 4.47. Structure of the gender composition of research specialists in 2022

Men predominated only among doctors of science (78%). But even here their number decreased by 165 people over the year.

The age composition of researchers is considered one of the basic characteristics of the effectiveness of research activities.

In 2022, the number of personnel in the under-25 years old group decreased by 14 people and in the 25-34 years old group by 33 people. In other age groups, there was an increase from 58 people to 612 (table 4.45). In the personnel structure, the largest percentage (29%) falls on the age of 35-44 years - the most productive age (table 4.3).

Table 4.31. Distribution of the number of employees performing research and development by age

	2020	2021	2022	Increase/ decrease (–)	Personnel structure, %
Total, *person*	22 665	21,617	22 456	839	100
up to 25 years	1,535	1 260	1,246	-14	5.5
25–34 years	5,771	5 448	5 415	–33	24.1
35–44 years	5 832	5 831	6 443	612	28.7
45–54 years	4,060	4,023	4 173	150	18.6
55–64 years	3 381	3 213	3,279	66	14.6
65 years and older	2,086	1,842	1 900	58	8.5

According to the Bureau of National Statistics ASPR RK

It should also be taken into account that the share of women scientists in Kazakhstan accounts for 54%, a third of them are of reproductive age.

In 2022, there was a positive trend in the number of personnel with the highest scientific qualifications.

In the personnel structure, the largest share is made up of candidates of science - about 18% and PhD doctors - 11% (table 4.32).

Table 4.32. Distribution of personnel by qualification

human

	2020	2021	2022	Increase/ decrease (–)	Personnel structure, %
Total R&D personnel	22 665	21 617	22 456	839	100
Of these, research specialists	18228	17,092	18,014	922	80.2
of them qualified:					
Doctor of Sciences	1883	1 652	1,743	91	7.8
candidate of sciences	4324	3,838	3 945	107	17.6
PhD	1755	1,952	2 460	508	11.0
doctors by profile	62	55	96	41	0.4

According to the Bureau of National Statistics ASPR RK

The increase in the number of personnel in 2022 was mainly due to research specialists, whose number increased by 922. At the same time, the number of technicians whose job duties require technical knowledge and experience decreased by 41 people, other support workers - by 42 people (table 4.33).

Meanwhile, the overall increase in the number of employees was unevenly distributed across sectors of activity. There was a significant decline in the government and business sectors. The largest decrease - by 997 people - was observed in the public sector. In the business sector, the number of employees decreased by 720 people. The number increased by 2.4 thousand people in the higher professional education sector and by 188 people in the non-profit sector.

Table 4.33. Number of personnel engaged in research and development, by personnel category and sector of activity

human

	2020	2021	2022	Increase/ decrease (–)	Personnel structure, %
Total	**22 665**	**21,617**	**22 456**	**839**	**100**
Researchers	18 228	17,092	18,014	922	80.2
Technicians	2,686	2 824	2,783	–41	12.4
Others	1,751	1 701	1,659	–42	7.4
including by sectors of activity:					
government sector	*7 221*	*7 611*	*6,614*	*–997*	*29.5*
higher education sector	*9 415*	*8 157*	*10 525*	*2 368*	*46.9*
business sector	*4 177*	*3,975*	*3 255*	*–720*	*14.5*
non-profit sector	*1,852*	*1,874*	*2,062*	*188*	*9.2*

According to the Bureau of National Statistics ASPR RK

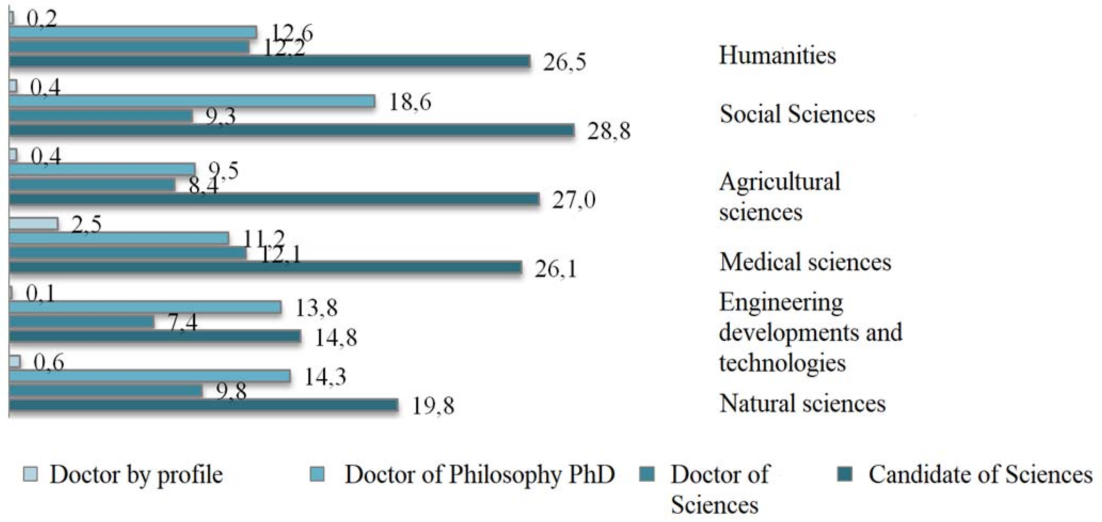
In 2022, as in previous years, the most researchers are involved in the field of natural sciences – 5,6 thousand people (31%). The field of engineering development and technology accounts for 4,2 thousand people (24%), Humanities – 3,1 (17%), Social Sciences – 1,9 (10%), Agricultural and Medical Sciences – 1,6 thousand people or 9% each (table 4.34).

Table 4.34. Distribution of research specialists by branches of science for 2022

Indicators	Total	of which by branches of science					
		natural	engineering and technology	medical	agricultural	social	humanities
Research specialists, *people*	18,014	5605	4278	1609	1555	1870	3097
of which those with a degree:							
Ph.D	1,743	551	315	194	131	174	378
PhD	3 945	1110	635	420	420	538	822
Doctor of Philosophy PhD	2460	803	592	180	147	348	390
doctor by profile	96	31	6	40	6	7	6
master	5397	1723	1182	403	515	630	944
***For reference:** Availability of personnel of the highest scientific qualifications, people per 100 research specialists*	*46*	*45*	*36*	*52*	*45*	*57*	*52*

According to the Bureau of National Statistics ASPR RK

In the reporting year, 57 people out of 100 people had higher scientific qualifications in the field of social sciences, medical and humanities - 52 people each, agricultural and natural sciences - 45 people each, engineering and technology - 36 people. It should be noted that in all branches of science, the number of candidates of science dominates over all other personnel of the highest scientific qualifications (fig. 4.48).



According to the Bureau of National Statistics ASPR RK

Figure 4.48. Specialists with the highest scientific qualifications per 100 research specialists in the industry in 2022

The quality of scientific research is determined not only by the content and methods of conducting and implementing research results, but also by the qualifications of the scientist, which, first of all, depends on the quality of training of scientific personnel. This process is in the nature of the reproduction of scientific personnel, which is provided through master's and doctoral studies in educational organizations under postgraduate education programs.

In the 2022/2023 academic year, 105 organizations trained master's students, and 73 doctoral students. As can be seen from the statistics, the number of organizations with master's training programs increased by 3 units, and the number of doctoral training decreased by one organization (table 4.35).

Table 4.35. Number of organizations training scientific and teaching personnel

units

	2019/2020 academic year	2020/2021 academic year	2021/2022 academic year	2022/2023 academic year
Master's degree	114	109	102	105
Doctoral studies	78	79	74	73

According to the Bureau of National Statistics ASPR RK

Doctoral studies. At the beginning of the 2022/2023 academic year, 6156 people were registered in doctoral studies, of which 3878 people, or 63% were women. The number of accepted doctoral students in the reporting year was 1711 people, those who dropped out before graduation were 310 people, and the number of doctoral students who completed training beyond the established period was 408 people. The graduation rate of doctoral students amounted to 1536 people, of which 234 people or 15.2% defended their dissertation (table 4.36).

The number of doctoral students in the relevant field is 135 people and doctoral students in philosophy (PhD) – 6021 people.

Table 4.36. Number and graduation of doctoral students

human

	2020	2021	2022
Number of doctoral students (at the end of the year) – total	6914	5924	6156
including:			
doctoral students by profile	237	144	135
doctoral students (PhD)	6677	5780	6021
Admission of doctoral students – total	2094	1,720	1711
including:			
doctoral students by profile	78	39	35
doctoral students (PhD)	2016	1981	1676
Doctorate graduation – total	1446	2503	1536
Defended a dissertation from the general issue*	483	642	234

According to the Bureau of National Statistics ASPR RK

*Hereinafter – the number of persons who defended dissertations during doctoral training (i.e. within the doctoral period specified in the enrollment order)

The most represented by the number of students in doctoral studies are: engineering, manufacturing and construction industries - 16.7% each, pedagogical sciences - 15%, natural sciences, mathematics and statistics - 12.8%, information and communication technologies - 5.6%.

Data show that the number of doctoral students compared to the previous year, 2021, increased by 232 people.

The main contingent of students consists of PhD doctoral students - 98% (previously, it was 97.6%), and the share of doctoral students in the field accounts for about 2%. The Class of 2022 was 1536.

One of the main characteristics of assessing the quality of training of scientific personnel is the number of defended dissertations during the period of doctoral study.

In 2022, the number of those who defended their rights amounted to 234 people or 15.2%, decreasing the position by 10,4 percentage points compared to the previous year.

The data show that graduation with a thesis defense of all graduates *was not produced in any of the majors.*

The main reasons for such low defense rates, compared to the number of applicants, is the fairly high attrition rate of doctoral students during the period of study. Thus, 980 people dropped out before graduation in three years of doctoral studies, and 480 completed doctoral studies beyond the established period.

Meanwhile, as competent sources note, high attrition can be considered as « natural selection» and is not a disadvantage in doctoral studies.

The number of doctoral students who defended their dissertation was higher than the national average in five specialties of the scientific and pedagogical direction: pedagogical sciences, veterinary medicine, arts and humanities, health and social welfare (medicine), natural sciences, mathematics and statistics, and social sciences, economics and business in the profile direction. The training of doctoral students in the specialized field is being reduced, and the recruitment of doctoral students is not ongoing (table 4.37).

Table 4.37. Distribution of doctoral students by specialty, their admission and graduation in the 2022/2022 academic year*

human

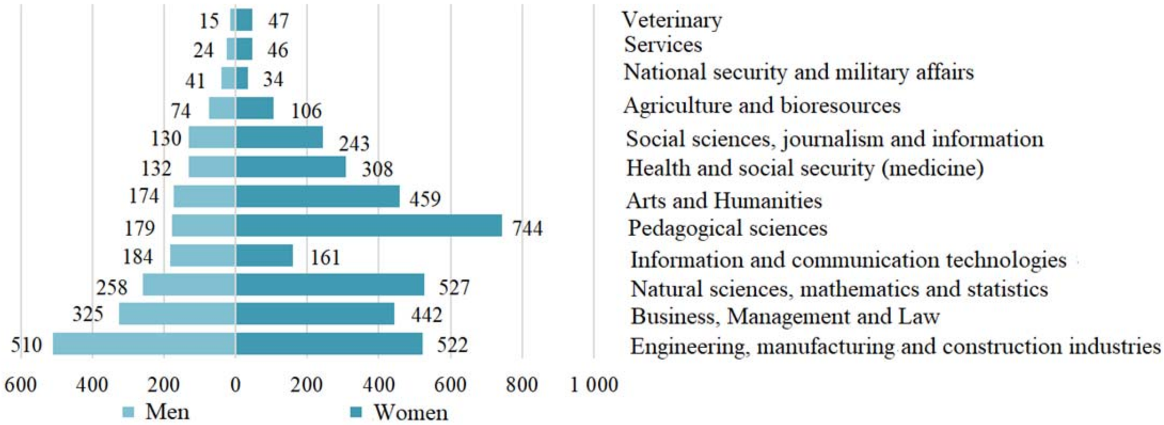
Name of directions and specialties	Number of doctoral students	Accepted doctoral students in the reporting year	Graduated doctoral students in the reporting year	Released with disser-tation defense	Share of graduates with dissertation defense, %
Total	**6156**	**1711**	**1536**	**234**	**15.2**
Scientific and pedagogical direction					–
Pedagogical Sciences	923	296	221	74	33.5
Arts and Humanities	633	182	191	40	20.9
Social sciences, journalism and information	373	102	122	5	4.1
Business, management and law	767	211	173	14	8.1
Science, mathematics and statistics	785	199	203	32	15.8
Information and communication technologies	345	84	127	9	7.1
Engineering, manufacturing and construction industries	1,032	294	267	7	2.6
Agriculture and bioresources	180	45	19	1	5.3
Veterinary	62	16	9	3	33.3
Health and social care (medicine)	440	129	130	27	20.8
Services	70	26	15	–	–
National security and military affairs	75	19	12	–	–
Profile direction					
Education	1	–	–	–	–
Humanitarian sciences	9	–	–	–	–
Social Sciences, Economics and Business	34	–	eleven	3	27.3
Natural Sciences	7	–	–	–	
Engineering Science and Technology	27	–	1	–	–
Agricultural Sciences	1	–	–	–	–

According to the Bureau of National Statistics ASPR RK

*In the Nazarbayev University report, the number of doctoral students is not distributed by specialty.

An analysis of the gender composition of doctoral students in the scientific and pedagogical field shows that women significantly predominate in most specialties. A numerical superiority of men is observed only in such specialties as Information and Communication Technologies, National Security and Military Affairs (fig. 4.49).

Human



According to the Bureau of National Statistics ASPR RK

In the Nazarbayev University report, the number of doctoral students is not distributed by specialty

Figure 4.49. The structure of the gender composition of the scientific and pedagogical direction of doctoral student training in the 2022/2023 academic year

According to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 393 Master’s Degree from the CIS countries are studying in educational institutions of the republic. In addition, 504 master’s students are studying from non-CIS countries. The largest number of foreigners arrived from China - 203, Afghanistan - 122, Nigeria - 53, Pakistan - 31.

118 foreigners are studying for doctoral studies, including 29 people from the CIS countries and 89 people from foreign countries. The increase in the number of foreign master's and doctoral students can be considered a positive phenomenon. In the future, foreign students may be of interest for conducting joint scientific research.

Conclusions. Analysis of statistical data on the increase in the number of researchers shows that the action plan for the implementing of the Concept of Science Development is being successfully implemented. In general, in 2022, there is an increase in the number of both general personnel and specialist researchers. This helps to increase the staffing of scientific organizations, which should positively impact the quality of research. However, few graduates of postgraduate training enter the field of scientific research. Thus, only 69 PhD doctors out of the 1,500 people graduating from doctoral programs in 2022 have entered the research field. This rate of personnel renewal does not make up for losses due to attrition due to natural reasons, such as retirement, since the number of personnel of pre-retirement and retirement age makes up a quarter of all employees engaged in research activities.

5. ANALYSIS OF FINANCING OF RESEARCH AND DEVELOPMENT (funded by the state budget, attracting funds for science from the private sector)

Statistics show that the volume of gross domestic product (GDP) produced in January-December 2022 (according to preliminary data) amounted to 101,522 billion tenge. Compared to the corresponding period of the previous year, it increased in real terms by 23,5% (table 5.38).

Table 5.38. Structure of gross domestic product for 2022

	January - December 2022 million tenge*	To the corresponding period of the previous year		In percentages to the end
		Physical volume index	Deflator	
Gross domestic product	**101,522,983.70**	**103.2**	**117.2**	**100**
Production of goods	*40,335,725.50*	*103.2*	*115.5*	*39.8*
Service production	*53,407,849.70*	*102.6*	*115*	*52.5*
Gross value added	***93,743,575.20***	***102.9***	***115.2***	***92.3***
Net taxes on products	*7,779,408.50*	*107.9*	*148.5*	*7.7*

According to the Bureau of National Statistics ASPR RK
*According to preliminary data

GDP is basically the sum of the cost of goods in the manufacturing sector of the economy and ***the costs of providing services***, including professional scientific and technical activities, including R&D costs, i.e. costs incurred to discover new knowledge and convert it into new products or processes as they arise.

The ratio of production of goods and production of services in GDP for 2022 was 39,8% and 52,5%, respectively. The main share in the production of goods in GDP is industry – 29,4%.

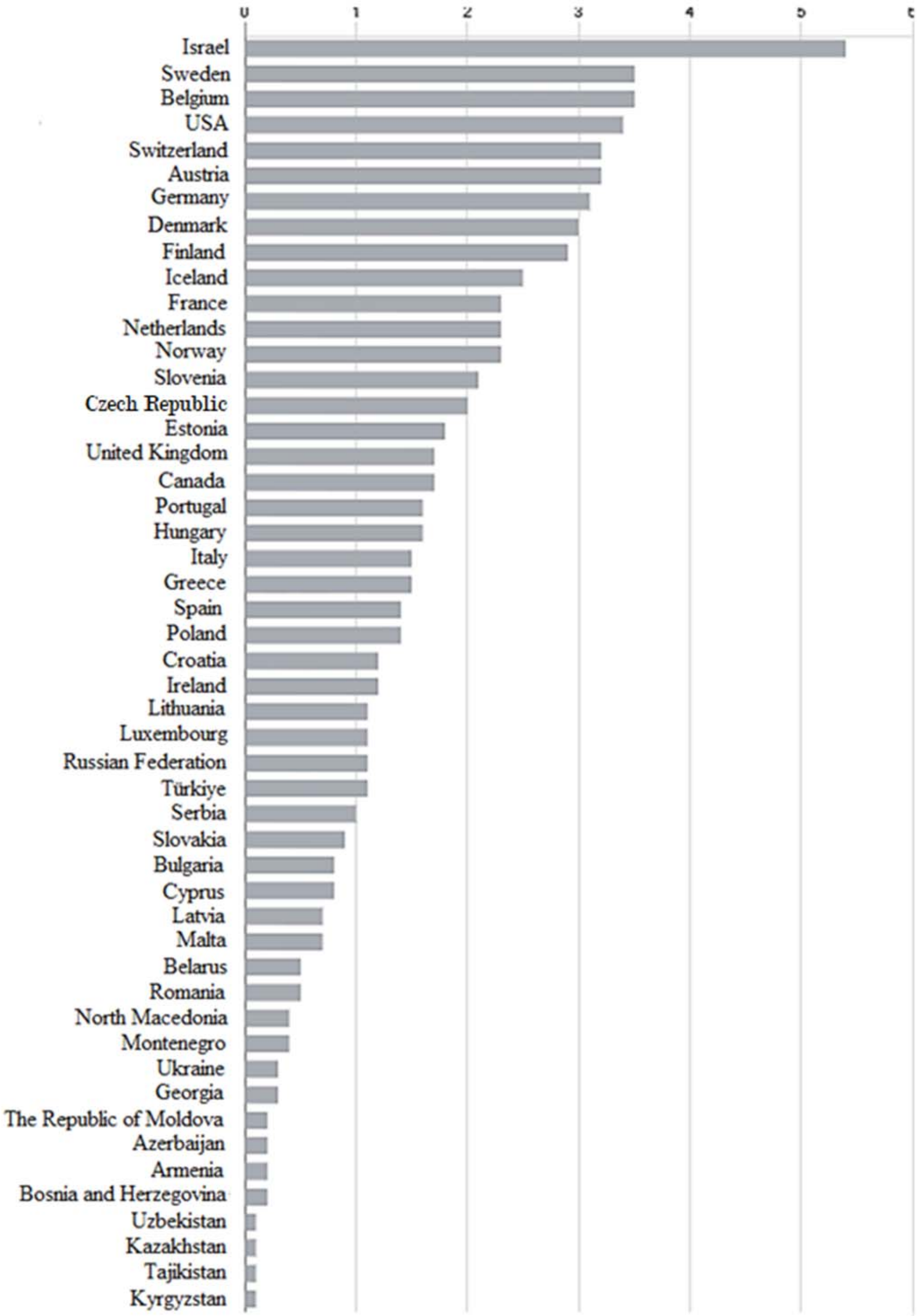
Global R&D spending has stood at nearly $1.7 trillion over the past few years. According to the data, all major economies are in the top five for R&D spending: the United States, followed by China, Japan, Germany and the Republic of Korea. However, the ranking changes when R&D expenditure is considered as a percentage of GDP: the Republic of Korea is the global leader, followed by Israel, Japan, Finland and Sweden.

As part of the Sustainable Development Goals, most countries in the world, incl. Kazakhstan has committed to significantly increase R&D spending and the number of researchers by 2030.

Analysis of the structure of R&D costs allows us to understand the ways and possibilities of their regulation.

In Kazakhstan, the science intensity of GDP in recent years has remained at the level of 0,13% and, according to the UN Economic Commission for Europe, in terms of this indicator it occupies one of the last places among the countries of the world (fig. 5.50).

in % of GDP



Source: UNECE Knowledge Center on SDGs : Sustainable Development Goals .Indicator 9.5.1. https://w3.unece.org/SDG/ru/Indicator?id=123

Figure 5.50. Research and development costs as a percentage of GDP by country, %

At the same time, the share of public investment in R&D exceeds 50% on average. Consequently, investments from all other sources account for less than half.

Government funding plays a significant role in stimulating and supporting R&D. First of all, this is justified by the fact that the creation of new scientific knowledge requires significant investment, and the guarantees of its commercialization and income generation are very small. Therefore, representatives of the business sector are reluctant to take risks associated with financing scientific research.

The government funds scientific research because the real value of R&D is the resulting knowledge, which can benefit society as a whole in terms of education, health, environmental care, etc.

In Kazakhstan, the main source of R&D funding is the state. In 2022, the volume of budget funds increased by 7.0 billion tenge, reaching 71,5 billion tenge (table 5.39).

Table 5.39. Sources of financing internal R&D costs

billion tenge

	2020	2021	2022
All costs, billion tenge.	**89.0**	**109.3**	**121.6**
of them:			
budget funds	49,711.8	64,542.5	71,573.5
own funds of scientific organizations	35.5	36.5	28.0
foreign investment	2.2	2.1	2.8
bank loans	0.1	0.04	0.1
other sources of financing, including funds from legal entities (except for development institutions)	4.9	6.6	8.6
All costs, %	**100**	**100**	**100**
of which by funding source:			
budget funds	51.2	53.6	67.0
own funds of scientific organizations	39.9	33.4	23.1
foreign investment	2.5	1.9	2.3
bank loans	0.1	0.0	0.1
other sources of financing	5.5	6.0	7.1

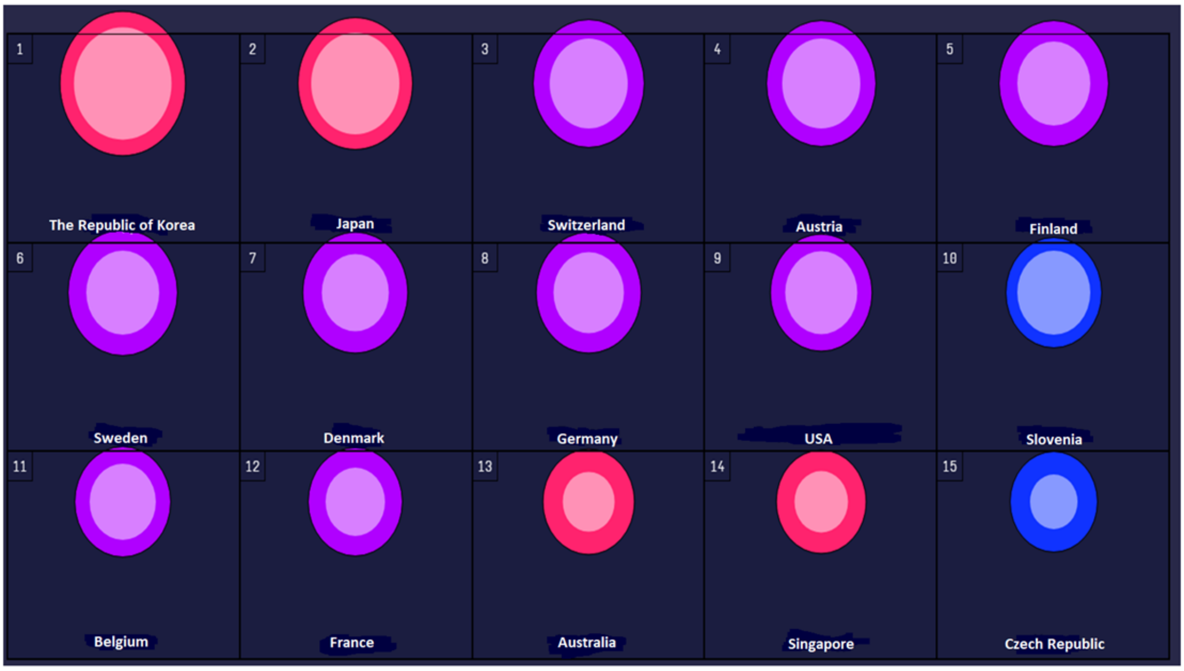
According to the Bureau of National Statistics ASPR RK

The second main source of R&D financing is organizations' own funds, but in 2022 they decreased by 8.5 billion tenge or 23,1%.

In general, the overall picture of funding sources demonstrates the process of crowding out all other sources by government spending. So, if three years ago the share of budget funds was slightly more than 50%, then in 2022 it is close to 70%. Compared to the previous year, it increased by 7,4 percentage points.

Many countries are attempting to stimulate increased investment in both the private and public sectors by setting national targets for R&D costs as a percentage of GDP.

The UNESCO Institute for Statistics identified 15 countries with a high share of R&D expenditures and a high share of business sector investment in research. The outer circle shows the share of R&D costs in the country's GDP - the science intensity of GDP, the inner circle shows the share of the business sector in total R&D costs (fig. 5.51).



Source: How much does your country invest in R&D? (unesco.org)

Figure 5.51. Ratio of the share of R&D costs in GDP and the share of business sector costs in R&D investments

The figure shows that in countries with the highest research intensity of GDP, investment from entrepreneurs exceeds other sources of financing. Thus, in the Republic of Korea, the share of R&D costs in GDP is 4,1%, while the share of the business sector in total R&D costs is 78,2%. In the Czech Republic, these figures are 2% and 55,2%, respectively.

Analysts from the UNESCO Institute of Statistics, based on statistical data, suggest that an increase in government funding leads, firstly, to inefficient use of resources [392]; secondly, it suggests that strategic goals in the field of R&D are either irrelevant or unattractive for entrepreneurs.

Financing of scientific and (or) scientific and technical activities from the state budget in Kazakhstan is carried out in the form of basic, grant and program-targeted funding. In addition, since 2022, the state budget has been financing scientific organizations that carry out fundamental scientific research (table 5.40).

Table 5.40. Internal costs aimed at performing R&D, from the republican budget, by form of financing

million tenge

Indicators	2020	2021	2022
Total from the republican budget	49,711.8	64,542.5	71,573.5
of them:			
Basic	5,317.5	5,715.1	7,406.6
Grant	16,669.7	19,608.5	29,499.3
Program-targeted	22,324.6	34,358.9	33,051.6
incl. financing of scientific organizations carrying out fundamental scientific research			799.5
Grant funding for RSSTA commercialization projects	5 400	4,860	1,616

As the data shows, the cost structure by form of financing has changed significantly over time.

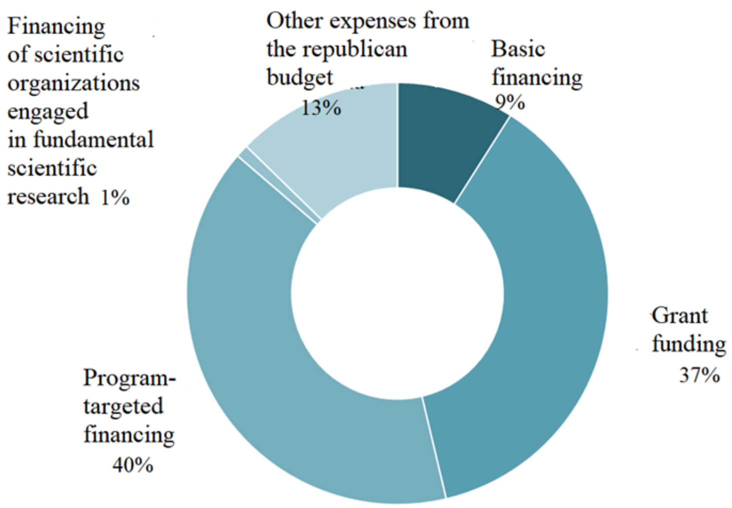
Basic financing includes expenses for the ongoing provision of scientific infrastructure and property, including buildings, equipment and materials, remuneration of administrative and service personnel, as well as information support for the scientific and technical activities of subjects.

Grant funding is provided free of charge and irrevocably from the state budget for the implementation of fundamental and applied scientific research and is carried out on a competitive basis within the limits of funds provided for in the state budget.

Any accredited subjects of scientific and (or) scientific and technical activities have the right to take part in the competition for grant funding on equal terms, therefore this type of funding was distributed fairly evenly between public and private organizations.

Program-targeted financing is aimed at solving strategically important government tasks and is carried out on a competitive basis or by decision of the Government of the Republic of Kazakhstan outside of competitive procedures. The basis for program-targeted financing of scientific research is the strategic plans for the socio-economic development of the country, industrial and innovative development programs and other programs aimed at implementing strategically important government tasks.

Data show that the main direction of public investment is program-targeted and grant projects, which account for 40 and 37% of total funding (fig. 5.52).



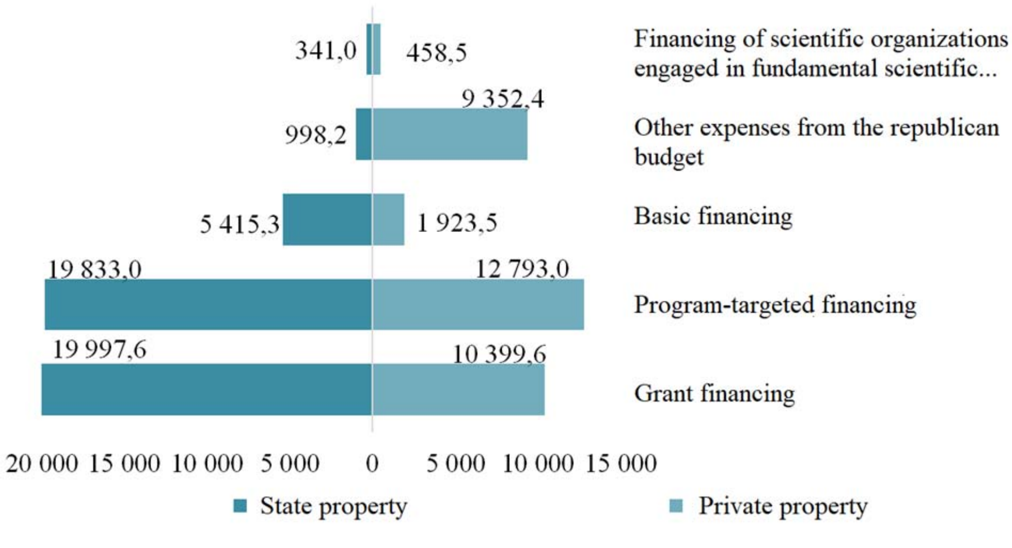
According to the Bureau of National Statistics ASPR RK
Figure 5.52. Structure of financing from the republican budget by form of financing

Basic funding is 9%, funding for scientific organizations carrying out basic scientific research is 1% and other costs from the republican budget related to research and development are 13%.

In 2022, 132 programs and 1961 projects were implemented in Kazakhstan. Based on the data provided by statistics on the amounts received by implementers in the form of grants and/or program-targeted financing, we obtain that on average 1 project accounts for 15,5 million tenge, per program – 247,2. To understand how financially secure these studies are, we can compare them with the average monthly nominal wages of workers in such types of activity as « Professional, Scientific And Technical Activities", which includes «Scientific Research and development», which is equal to 534 673 tenge. It turns out that grant funding for one project is equal to approximately the annual salary of 2,5 people, and one program, in which more than one research team can participate, is equal to 38,5 people. While mandatory payments, such as salaries and expenses for raw and other materials used in research, and rent, account for about 80%, there are no funds left for the development and renewal of fixed assets (machinery, equipment, etc.). It may be worth reducing the number of simultaneous studies conducted with public funds.

In 2022, funding for state organizations from the republican budget amounted to 5,4 billion tenge compared to 1,9 billion tenge of privately owned organizations. Moreover, other things being equal, there is a clear defense of the interests of state-owned organizations for grant and program-targeted financing. A slight predominance was noted for private organizations carrying out basic research, and about 9 billion tenge was provided from the republican budget to cover other expenses related to R&D (fig. 5.53).

million tenge



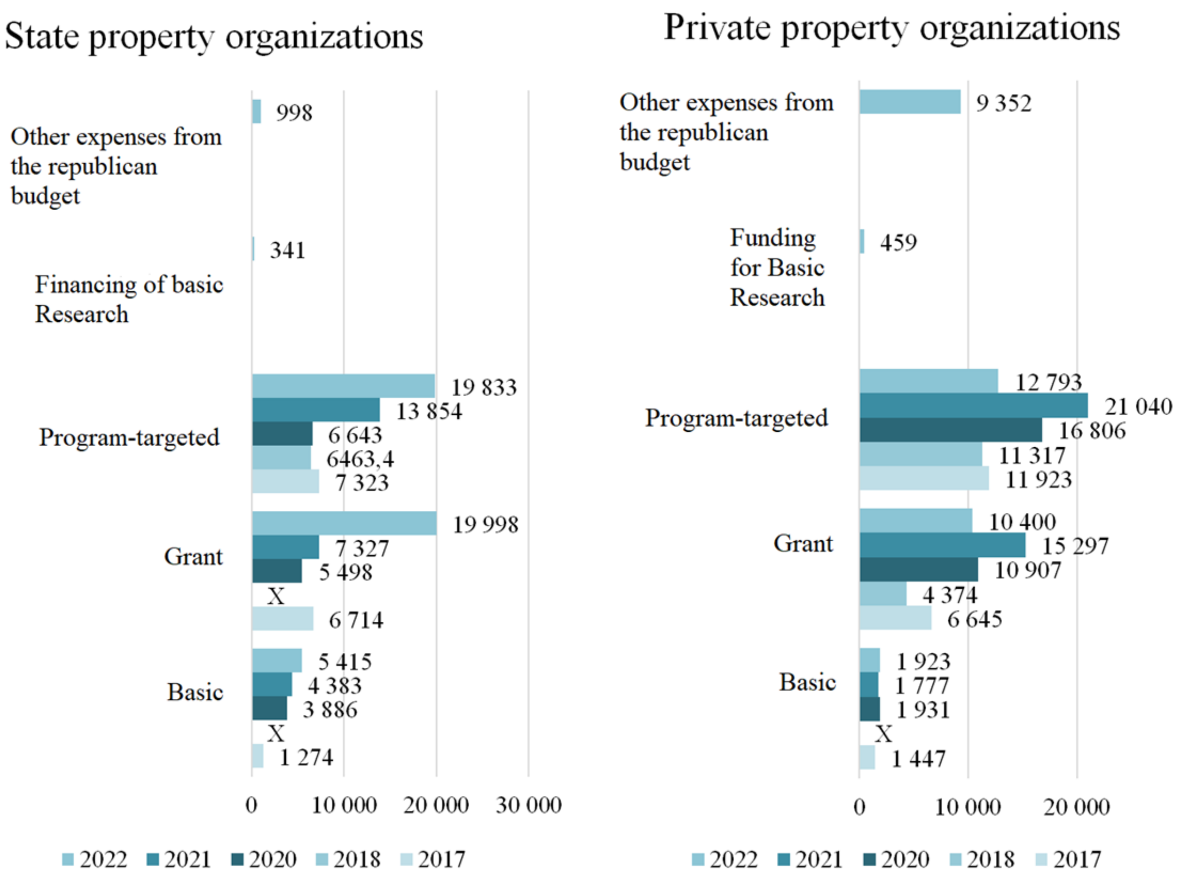
According to the Bureau of National Statistics ASPR RK

Figure 5.53. Financing of R&D from the republican budget in 2022 by type of ownership of organizations

At the same time, with a general decrease in funds of 2,3 billion tenge for program-targeted financing, most of them went to the implementation of scientific, scientific and technological programs carried out in state-owned organizations. The volume of grant funding for government organizations was almost 2 times higher than the volume of funding for private ones, amounting to almost 20 billion tenge.

The following dynamics are noted considering government funding of organizations by ownership type. Expenditures on scientific projects from the republican budget, carried out by privately owned organizations for several years, exceeded the costs of government organizations by 1,5–2,5 times. However, in the last year 2022, they have sharply decreased by an average of 50%. Most of all, this process affected projects of program-targeted financing. Thus, in 2022, their financing decreased by more than 8 billion tenge or 39% (fig. 5.54).

million tenge



According to the Bureau of National Statistics ASPR RK

Figure 5.54. Dynamics of financing of internal R&D costs by type of ownership of organizations for 2020–2022.

There is no economic explanation for this phenomenon.

Domestic research and development (R&D) expenditure **as a share of gross domestic product** (GDP) measures the contribution of science to GDP rather than research funding. R&D costs show the volume of the scientific product produced and, as an intangible object, is measured by its production costs.

In order to achieve the goals of increasing R&D costs, financed from all sources up to 1% of GDP, set by the Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023–2029 (approved by Resolution of the Government of the Republic of Kazakhstan dated March 28, 2023 № 248), it is necessary to explore the formation of costs by item.

According to the Methodology for generating indicators of statistics of research and development work and innovation [350], the volume of R&D costs is equal to expenses for the following items: wages, purchase of services, fixed assets, other current costs (table 5.41).

Table 5.41. Internal R&D costs by cost item in 2022

million tenge

Index	Total	Government sector	Higher education sector	Business sector	Non-profit sector
Internal R&D costs	121,560.1	38,025.0	37,694.9	31,921.4	13,918.8
of them					
labor costs	58,482.2	21,502.5	19,151.5	10,020.8	7,807.4
purchase of services (for own projects)	15,411.2	3,742.5	4,252.2	4,622.5	2,794.0
costs of fixed assets (machinery, equipment, buildings and others)	11,279.1	4,085.7	4,700.6	1,631.3	861.4
other operating costs (consumables, raw materials and equipment, rent and others)	4,669.8	1,919.4	1,771.1	725.3	254.1
External R&D costs	36,387.6	8,694.3	9,590.6	15,646.8	2,456.0

According to the Bureau of National Statistics ASPR RK

According to global standards, labor costs for personnel performing R&D constitute the largest portion of current costs. Compensation includes wages and other related payments and expenses: bonuses, vacation pay, contributions to pension funds and other contributions to social insurance funds, labor taxes.

In 2022, labor costs amounted to almost 58,5 billion tenge, which exceeds the previous year's figure by 9,8 billion tenge or 20,1%. A cost increase is noted by 3,1 billion tenge in the public sector, by 9,8 billion tenge in the sector of higher professional education, and by 2,0 billion tenge in the non-profit sector. At the same time, they decreased by 5,2 billion tenge in the business sector.

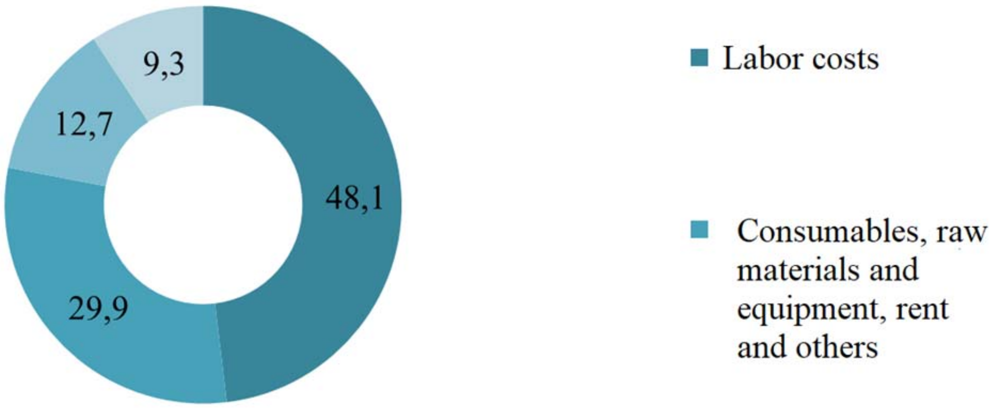
The increase in labor costs in nominal terms increased their share in domestic costs by 3,6 percentage points, amounting to 48,1% in 2022 (fig. 5.55).

The average monthly salary of workers performing R&D in 2022 amounted to 217 thousand tenge (table 5.42).

However, if we take into account the full-time equivalent of workers performing R&D, equal to 0,76, the average monthly nominal wage was 285 thousand tenge. Over the same period, the average monthly nominal salary of one employee in Kazakhstan as a whole amounted to 269 thousand tenge [351].

On average, scientists' salaries increased by almost 16%. Above-average growth occurred in the public (35%), higher education (59%) and non-profit sectors (23%). In the business sector, wages decreased by 19% compared to the previous year.

in percentages



According to the Bureau of National Statistics ASPR RK
Figure 5.55. Structure of internal R&D costs in 2022

Table 5.42. Average monthly wages of workers performing R&D by sector of activity

thousand tenge

Year	By organizations engaged in R&D	including			
		government sector	higher education sector	business sector	non-profit sector
2020	151.9	161.1	69.1	310.2	179.5
2021	187.7	201.3	95.5	318.4	256.1
2022	217.0	270.9	151.6	256.5	315.5

Calculated according to the Bureau of National Statistics ASPR RK

Despite the significant increase in wages, in general, it was significantly lower than inflation, and therefore could not significantly influence the increase in domestic costs.

For reference: according to the Bureau of National Statistics ASPR RK, since the beginning of the year (December 2022 compared to December 2021), prices and tariffs for consumer goods and services increased by 20,3% [352].

The next expense item is a *purchase of services* (for own projects). In 2022, 15,4 billion tenge was used for this expense item, which is 1,7 billion tenge less than in the previous year. The share of this expense item decreased by 3 percent, amounting to 12,7% of total costs.

Expenditures *on fixed assets* in 2022 amounted to 11,3 billion tenge or 9,3% of total R&D expenses. Compared to the previous year, costs for this item decreased by 1,5 billion tenge or 10,2%. Here it should be noted that the largest costs for the expansion of fixed assets fall on organizations in the public sector – 4,1 billion tenge and the sector of higher professional education – 4,7 billion tenge.

At the same time, costs for this item in the business and non-profit sectors have decreased significantly. In the business sector, costs amounted to 1,6 billion tenge (in 2021 – 3,6 billion tenge); for organizations of the non-profit sector – 0,9 billion tenge (in 2021 – 1,4 billion tenge).

Investments in fixed assets fluctuate annually between 8–12% of internal costs.

It should be noted that in 2022, 4,7 billion tenge or more than 41% of the cost of fixed assets was used for the purchase of scientific equipment.

Other operating costs, related to the purchase of consumables materials, raw materials and equipment, payment of rent, utilities and other services, increased by 1,8 percentage points in 2022, amounting to 36,4 billion tenge. They accounted for 29,9% of all domestic operating and capital expenditures for the year.

In general, it is clear that the increase in costs occurred for those items that are directly related to inflation, i.e. labor costs and costs of purchasing third-party services, such as rent, utilities and supplies. This increase was due to a reduction in expenses for fixed assets and for the purchase of services for own projects.

An analysis of domestic R&D costs by expenditure shows that it is impossible to achieve a knowledge intensity of GDP of 1% only by increasing them. For example, the manufacturing sector, which is the main consumer of scientific developments, is significantly inferior to the services sector in terms of GDP formation, so it is necessary to consider the possibility of shifting the vector of scientific research from the production sector to the service sector.

Given the limited ability to maneuver R&D costs by item, other options should be considered to help increase the share of R&D costs in GDP.

One of them is expanding the network of organizations involved in R&D. Organizations of higher professional education represent a large reserve in expanding research activities. According to state statistics, in the 2022/2023 academic year, 116 organizations were directly involved in training personnel with higher or postgraduate education, the scientific potential of which was 3 732 PhDs, 271 doctors in the field, 2656 doctors of science and 10 456 candidates of science.

In addition to human resources, higher professional education organizations have the potential for financial resources. For example, out of 578 thousand students, 365 thousand students or 63% receive paid educational services, which, according to government statistics, allows universities to receive income of about 150–200 billion tenge. The use of educational laboratory equipment and other material resources of educational organizations, as well as the involvement of master's or doctoral students in carrying out research work, will reduce their cost.

In addition to research organizations and organizations of higher professional education, organizations can be involved in R&D other types of activities, such as agriculture, industry, trade, information and communications, etc.

Overall, R&D spending continues to rise in 2022. Trends correlating with national indicators are observed in all sectors, except for business, the costs of which decreased by 6,3 billion tenge (table 5.43).

The growth index of R&D costs in 2022 was 11% with inflation of 20,3%, and additional funding from the republican budget was unable to cover inflation, which affected the intensity of R&D, i.e. share of R&D expenditures as a percentage of gross domestic product (GDP).

Table 5.43. Internal R&D costs by sector of activity

million tenge

	2020	2021	2022
Internal research and development costs, total	89,028.7	109,332.7	121,560.1
including			
government sector	28,847.2	37,143.6	38,025.0
higher education sector	14,795.6	21,194.3	37,694.9
business sector	36,832.9	38,215.7	31,921.4
non-profit sector	8,553.0	12,779.2	13,918.8

According to the Bureau of National Statistics ASPR RK

Growth below the republican average is observed in all sectors, except for the sector of higher professional education, where an increase of 1,8 times was recorded. In the public sector this figure was 2.4%, in the non-profit sector – 8,9%, in the business sector - a decrease of 16,5% (table 5.44).

Table 5.44. R&D cost growth index

in % to the previous year

	2020	2021	2022	Average growth for 2019–2021
Total	8.1	22.8	11.2	14.0
Government sector	18.8	28.8	2.4	16.7
Sector of higher professional education	10.6	43.2	77.9	43.9
Business sector	8.7	3.8	–16.5	–1.3
Non-profit sector	-20.7	49.4	8.9	12.5

Calculated according to the Bureau of National Statistics ASPR RK

The dynamics of such an irregular distribution of costs across sectors of activity indicates the absence of a specific and logical plan for the development of scientific research in the country. This negatively affects both the personnel component of the research process and the quality of research results.

Organizations of private ownership are more actively involved in performing work. In 2022, they spent almost 65 billion tenge, while the growth rate is quite high. In the reporting year, state-owned organizations' expenses increased 1,8 times and amounted to 54 billion tenge.

On the territory of the Republic of Kazakhstan, 13 foreign organizations are engaged in R&D. During the analyzed year, they spent 2,4 billion tenge (table 5.45).

Table 5.45. R&D costs by type of ownership of organizations

million tenge

	2020	2021	2022
Total	89,028.7	109,332.7	121,560.1
State property	20,513.1	29,886.7	54,132.2
Private property	66,413.3	75,998.9	65,049.6
Foreign ownership	2102.3	3,447.1	2,378.2

According to the Bureau of National Statistics ASPR RK

In 2022, there was a uniform increase in costs across all *branches of science*. As in previous years, engineering and technology accounted for 40% of all internal costs. Next come the natural sciences, which accounted for 29,6%, agricultural – 12,2, humanities – 7,6, medical – 6,5 and social (social) sciences with 3,8% (table 5.46).

Table 5.46. Internal R&D costs by branches of science

million tenge

Indicators	2020	2021	2022
Internal costs, total	89,028.7	109,332.7	121,560.1
including by branches of science			
Natural	25,228.7	31,707.0	36,030.0
Engineering developments and technologies (technical)	40,915.9	43,732.1	48,881.2
Medical	2,742.1	8,822.2	7,929.3
Agricultural	12,313.1	14,734.3	14,868.1
Social Sciences (Public)	2,653.0	3,037.1	4,584.5
Humanities	5,175.9	7,300.1	9,267.0

According to the Bureau of National Statistics ASPR RK

However, compared to the previous year, the largest increase in costs was observed in the social sciences (by 51%) and the humanities (27%); the smallest is for agriculture – 0,9%. Medical sciences saw a 10% decline.

In 2022, costs for *fundamental research* increased by more than 7,3 billion tenge, for applied research - by 8,1 billion tenge, the volume of costs for carrying out development work decreased by 3,2 billion tenge (table 5.47).

Table 5.47. Internal R&D costs by type of research and development

million tenge

	2020	2021	2022
Internal costs, total, million tenge	89,028.7	109,332.7	121,560.1
of them:			
basic research	14,143.8	20,639.8	27,907.1
applied research	54,462.3	68,925.7	77,041.6
Experimental development	20,422.7	19,767.2	16,611.4
Internal costs, %	100	100	100
of them:			
basic research	15.9	18.9	23.0
applied research	61.2	63.0	63.4
Experimental development	22.9	18.1	13.7

According to the Bureau of National Statistics ASPR RK

The data presented by the statistics are based on international standards adopted throughout the world, developed and approved by the OECD Committee on Science and Technology Policy (CSTP) and the OECD Committee on Statistics and Statistical Policy (CSSP).

For reference: Basic research is experimental or theoretical work undertaken primarily to obtain new knowledge about the fundamental basis of phenomena and observable facts, without any specific application or use.

Applied research is original research undertaken to acquire new knowledge. However, it is aimed primarily at a specific, practical goal or task. Applied research is undertaken either to determine possible uses of the results of basic research or to identify new methods or ways of achieving specific and predetermined goals. The results of applied research are intended primarily to validate their possible application to products, operations, methods or systems.

Experimental development is systematic work based on knowledge gained through research and practical experience, and the development of additional knowledge that is aimed at producing new products or processes, or improving existing products or processes.

(Est. OECD (2015), Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris. (paragraph 1.35, paragraph 2.30, paragraph 2.31)

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Based on the results of 2022, the following percentage ratio of fundamental, applied and experimental developments developed: 23/63/14. It follows from this that the costs of fundamental research, both in nominal terms and in shares, exceeded the costs of experimental design developments, thereby reducing the productive function of science, the results of which are intended for the introduction of innovations, innovations, new technologies, forms of organization and etc. This leads to the fact that the main direction of Kazakhstani science becomes a purely cognitive function, for the implementation of which almost two-thirds of the state budget funds are attracted.

Moreover, the Law of the Republic of Kazakhstan 11/15/2021. № 72-VII, an addition was adopted on the financing of scientific organizations carrying out basic scientific research from the state budget. The introduction of this addition led to an even greater expansion of basic research, including in regions, to the detriment of other species. It should be noted that in most regions there is a low supply of research specialists and a low full-time equivalent.

Based on the results of 2022, in the republic as a whole and in 11 regions of the country, the costs of fundamental research exceeded the costs of development, and the total share of fundamental and applied research in the regions ranges from 60 to 99% (table 5.48).

R&D is one of the main factors determining economic growth in developed countries producing industrial products of the fifth and higher technological structures. The share of costs for experimental design developments in these countries reaches 78%, and the ratio of fundamental, applied and experimental design developments corresponds on average to the following ratio: 15/35/50.

In 2022, in nine *regions* there was a decrease in costs: Aktobe region by 7,3 million tenge, Almaty region – by 399,0, Atyrau region – by 5 944.2, West Kazakhstan region – by 304,0, Zhambyl region – by 2 307.5, Kostanay - by 54,5, Turkestan - by 60,0, East Kazakhstan - by 1 140.0 and Shymkent - by 5,0 million tenge (table 5.49).

Table 5.48. – Characteristics of research availability in the regions of the Republic of Kazakhstan in 2022

	Internal costs, total, million tenge	Basic research, million tenge	Specialists-researchers, people	FTE	Share of research costs in the region by type of research, %		
					funda-mental	applied	Develop-ment Work
Republic Kazakhstan	121,560.1	27,907.1	18,014	0.76	23.0	63.4	13.7
Abay	3,996.7	206.5	798	1	5.2	90.5	4.3
Akmola	1,736.1	43.1	477	0.85	2.5	97.5	0.0
Aktobe	1,596.9	480.7	380	0.59	30.1	40.5	29.4
Almaty	1,148.7	247.8	179	0.91	21.6	78.2	0.3
Atyrau	467.8	158.4	104	0.5	33.9	66.1	0.0
Western Kazakhstan	994.7	58.4	403	0.43	5.9	93.2	0.9
Zhambyl	3,574.0	x	352	0.83	0.6	80.1	19.2
Zhetisu	127.2	37.4	305	1	29.4	69.4	1.2
Karaganda	5,363.5	1,325.1	980	0.5 3	24.7	73.0	2.3
Kostanay	1,036.8	x	411	0.47	4.5	54.3	41.1
Kyzylorda	526.6	93.3	218	0.72	17.7	70.0	12.3
Mangistau	13,521.0	25.9	601	1	0.2	91.1	8.7
Pavlodar	829.9	181.9	368	0.52	21.9	45.1	32.9
Northern Kazakhstan	8,839.7	x	118	0.57	0.4	3.5	96.2
Turkestan	659.9	134.8	204	0.94	20.4	58.5	21.1
Ulytau	3.6	–	2	1	–	0.0	100.0
Eastern Kazakhstan	5,881.6	333.3	691	0.75	5.7	64.9	29.4
Astana	22,961.0	7,988.2	3,554	0.74	34.8	62.2	3.0
Almaty	46,759.4	16,391.9	7 280	0.9	35.1	61.4	3.5
Shymkent	1,534.9	96.1	589	0.4	6.3	61.8	31.9

According to the Bureau of National Statistics ASPR RK

However, it should be borne in mind that the reduction in costs in the Almaty and East Kazakhstan regions is due to the fact that new regions with significant scientific potential were formed from these regions.

To analyze the uneven distribution of costs across regions, a Pareto diagram is used, reflecting the universal principle «20 percent of efforts provide 80 percent of success, and the remaining 80 percent provide only 20 percent of the result». The Pareto chart allows you to evaluate the efficiency of work, understand who brings the most results and focus maximum efforts on this.

The above diagram shows which regions of Kazakhstan make the greatest contribution to the research activities of the republic.

The histogram column shows the volume of R&D expenditures in million tenge in the region and is plotted on the left axis; the curve of the graph represents the accumulated percentage of R&D costs (i.e., the share of costs on an accrual basis). A threshold horizontal line is drawn across the conventional border of 80%. Five regions to the left of the point of intersection of this line with the cost

Table 5.49. Internal R&D costs by region

million tenge

Region	2020	2021	2022
The Republic of Kazakhstan	89,028.7	109,332.7	121,560.1
Abay region	0.0	0.0	3,996.7
Akmola	1,655.4	1,695.2	1,736.1
Aktobe	1,176.7	1,604.2	1,596.9
Almaty	1,672.8	1,547.7	1,148.7
Atyrau	5,801.8	6,412.1	467.8
West Kazakhstan	1,061.0	1,298.7	994.7
Zhambyl	2,156.2	5,881.5	3,574.0
Zhetisu region	X	X	127.2
Karaganda	3,986.4	4,718.8	5,363.5
Kostanay	788.1	1,091.3	1,036.8
Kyzylorda	283.9	429.3	526.6
Mangystau	10,428.2	11,089.6	13,521.0
Pavlodar	598.2	604.0	829.9
North Kazakhstan	339.4	411.1	8,839.7
Turkestan	481.9	719.9	659.9
Ulytau region	X	X	3.6
East Kazakhstan	5,412.2	7,021.6	5,881.6
Astana	18,753.0	20,529.0	22,961.0
Almaty city	32,873.3	42,738.7	46,759.4
Shymkent	1,560.2	1,540.0	1,534.9

According to the Bureau of National Statistics ASPR RK

accumulation schedule carry out 80% of the research in the republic, regions located to the right - the remaining 20%.

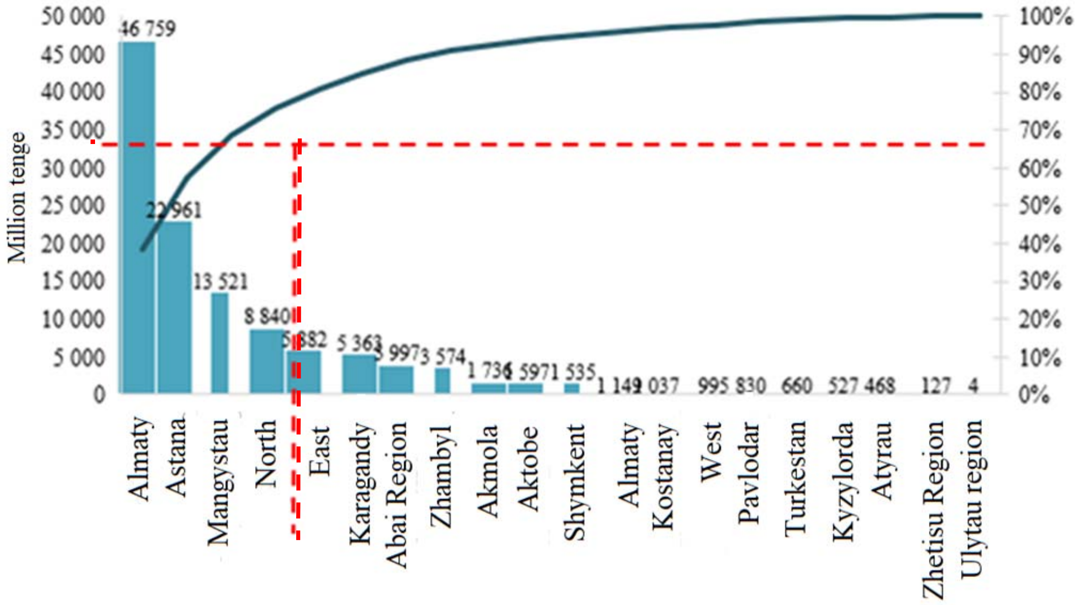
This ratio of the distribution of costs by region characterizes their preparedness, specialization and competence to carry out research activities.

The Pareto diagram shows that organizations in Almaty were the most prepared to carry out R&D in various areas and branches of science in 2022. The share of their costs in the total volume was 38,5 % and compared to last year it increased by 9,4% (fig. 5.56).

In the reporting year, the contribution of Astana science to total R&D costs increased by 11,8% and amounted to 18,9% of the republic’s internal R&D costs.

Mangistau region is in 3rd place in terms of the volume of annually increasing scientific research. It should be noted here that 96% of R&D in this area was financed from the organizations’ own funds, and 4% of public funds were spent on the implementation of programs and projects of program-targeted and grant funding. The independence of the region's scientific organizations from government funding made it possible to increase the monthly salary of its employees to 687 thousand tenge, which is more than three times higher than the national average salary level.

The fourth region in terms of R&D expenditures in 2022 was the North Kazakhstan region with 7,3% of the total republican volume. Costs in this region increased 22 times due to development work on engineering and technology.



According to the Bureau of National Statistics ASPR RK

Figure 5.56. R&D costs in 2022 according to the Pareto rule

The fifth region in the Pareto diagram is the East Kazakhstan region with 4,8%.

The remaining 15 regions account for a total of 20% of costs. The outsiders in the Pareto diagram are the Atyrau region and the Zhetysu and Ulytau regions.

In terms of R&D costs per employee, the North Kazakhstan region took first place with 54,9 million tenge. The next region, significantly exceeding the republican average, is the Mangistau region with costs equal to 20,5 million tenge per employee. Also higher than the national average, costs per employee in Zhambyl and East Kazakhstan regions are 8,8 and 5,9 million tenge, respectively.

These four regions significantly raised the republican average cost per employee, which in the republic amounted to 5.4 million tenge. For the rest, it ranged from 0.4 million tenge - in the Zhetysu region, to 5,4 million tenge - in Astana (table 5.50).

Conclusions. Domestic R&D expenditure is synonymous with research and development output and reflects the scientific activity of a country.

In general, the financial component of scientific potential for 2022 shows that R&D costs increased by 11.2%. However, this did not cover inflation, which in 2022 amounted to 20.3%. Significant investments from the state budget did not help either, the share of which in total costs was 9 percentage points higher than last year and amounted to 67,4%. The significant increase in government funding did not affect the research intensity of GDP, which decreased from 0,13% to 0,12%.

The share of own funds in R&D costs for 2022 decreased from 33,4% to 23,1%, i.e. by more than 10 percentage points. From an economic point of view, this indicates the inefficiency of the economic activities of scientific organizations, provided that most of the organizations belong to the business sector. Due to the weak demand for the results of scientific activities and the inability to repay the debt, and, possibly, the lack of business reputation of scientific organizations, such a financing instrument as bank loans for R&D is practically not used. And most importantly, funds from third-party legal entities invested in research and development in total costs amounted to only 5%.

Table 5.50. Internal R&D costs per employee engaged in research and development

million tenge

	2020	2021	2021
The Republic of Kazakhstan	3.9	5.1	5.4
Abay region			3.8
Akmola	2.3	2.2	2.3
Aktobe	2.7	4.2	3.8
Almaty	2.1	2.2	3.5
Atyrau	12.2	15.0	4.2
West Kazakhstan	2.1	2.9	2.4
Zhambyl	6.2	15.0	8.8
Zhetisu region			0.4
Karaganda	3.4	4.2	4.2
Kostanay	1.2	1.9	2.1
Kyzylorda	1.1	1.8	1.8
Mangystau	15.2	17.1	20.5
Pavlodar	1.2	1.4	1.7
North Kazakhstan	2.8	2.5	54.9
Turkestan	1.9	2.9	2.8
Ulytau region			1.8
East Kazakhstan	3.0	3.7	5.9
Astana	4.8	5.3	5.4
Almaty city	3.5	4.9	5.1
Shymkent	2.3	3.0	2.5

According to the Bureau of National Statistics ASPR RK

All this speaks to the unsatisfactory organization of the research and development process. It may be necessary to have a team in organizations alongside the researchers dedicated to developing a research strategy aimed at implementing R&D results. This will increase the responsibility and interest of scientists in the results of their work, especially since the state in every possible way contributes to the innovative renewal of production and allocates quite large funds for these activities.

In general, government R&D statistics in combination with other indicators such as the number of publications, citations, patents and industrial production data are useful in measuring the impact of R&D on countries' economic and social development.

6. ANALYSIS OF WORLD TRENDS IN THE DEVELOPMENT OF SCIENCE (discoveries and achievements obtained by Kazakhstani science as a result of the implementation of scientific and technical agreements with foreign and international scientific organizations)

In modern conditions, one of the main development trends is the globalization of international economic relations, when there is a need to unite the efforts of interested parties in the world community to solve scientific and technical problems, exchange experience, and search for new knowledge. The growing need for interdisciplinary research, a high degree of uncertainty and risk in obtaining results, the desire to minimize the duplication of expensive research, a number of scientific and technical problems, mainly socio-economic orientation (health issues, food problems, space exploration, preservation of environmental quality, etc.), have global significance, which leads to the need to unite the efforts of states to solve them [353, 354].

To carry out joint research, stable, structurally organized research groups (teams) are created with a certain set of values and value orientations, working in the same direction and having a research program adopted by the subjects of this association. Associations are emerging that unite researchers from different scientific schools and areas [355].

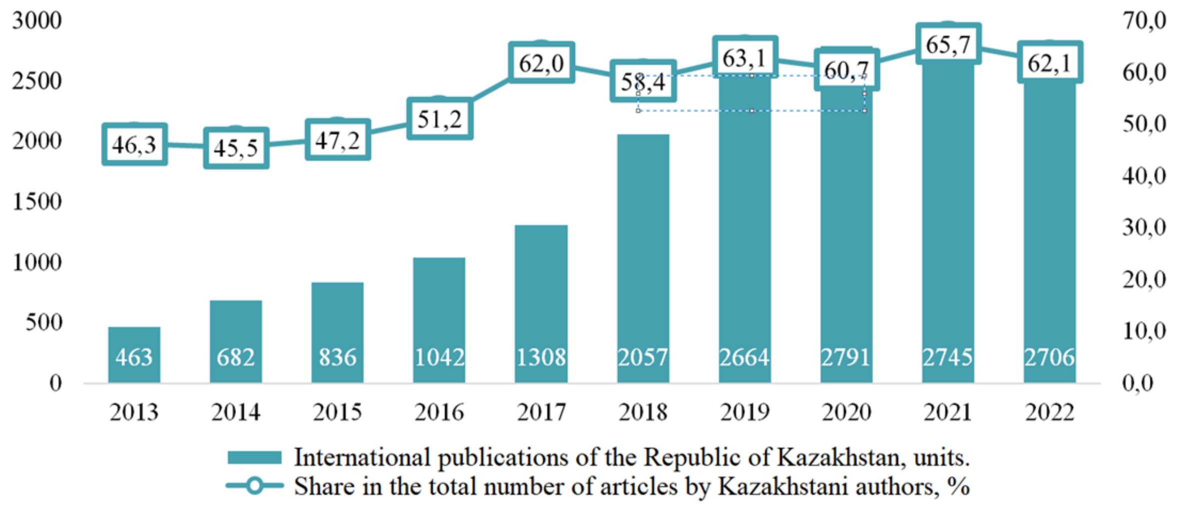
In addition, at present there are all the prerequisites for increasing the internationalization of science. This is, first of all, the active entry of computer technology into our lives, a radical change in access to scientific information, facilitating the expansion of opportunities for direct contacts between scientists from different countries, e-mail, online conferences, providing the possibility of prompt contact between scientists, intensive discussion of problems of interest, informatization of scientific research etc. [356,357].

The Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023–2029 dated March 28, 2023 № 248 indicates the development of international scientific and scientific-technical cooperation as one of the main principles for the development of the country's system of higher and continuing education and science.

Web of Science citation database as the main indicators of cross-country interaction.

An analysis of the dynamics of joint articles by domestic researchers with foreign scientists over a 10-year period shows a significant increase in their number and some stabilization after 2019. At the same time, the trend towards stabilization of the share of international publications in the total body of Kazakhstani works has been observed since 2017 and fluctuates between 58–66% (fig. 6.57).

For the period 2020–2022 the share of international cooperation in Kazakhstan was 61,3%, while the world average is 23,5%. A comparison of the values of the share of international cooperation with the total number of publications shows that developed countries with high publication activity are mostly characterized by shares of cooperation below 60%. While developing countries are represented in the database by a small number of publications, the bulk of which were prepared in collaboration with other countries (fig. 6.58).



According to Web of Science (Clarivate Analytics), as of 01.06.2023.
Figure 6.57. Dynamics of Kazakhstani publications prepared in international cooperation

According to InCites (Clarivate Analytics), 2020–2022 gg., as of 01.06.2023
Figure 6.58. Publication activity and share of international cooperation in various development countries, 2020–2022.

Along with the growth of publications, the geography of Kazakhstan's partner countries is expanding: 2018–2020 – 176 countries; 2019–2021 – 180; 2020–2022 – 182 countries. The main scientific partner of Kazakhstan is Russia, with which in 2020–2022. More than a third of all works have been published, followed by the USA and China, as well as Great Britain, England and Germany, which are consistently among the top 10 countries of the republic's scientific partners (fig. 6.59).

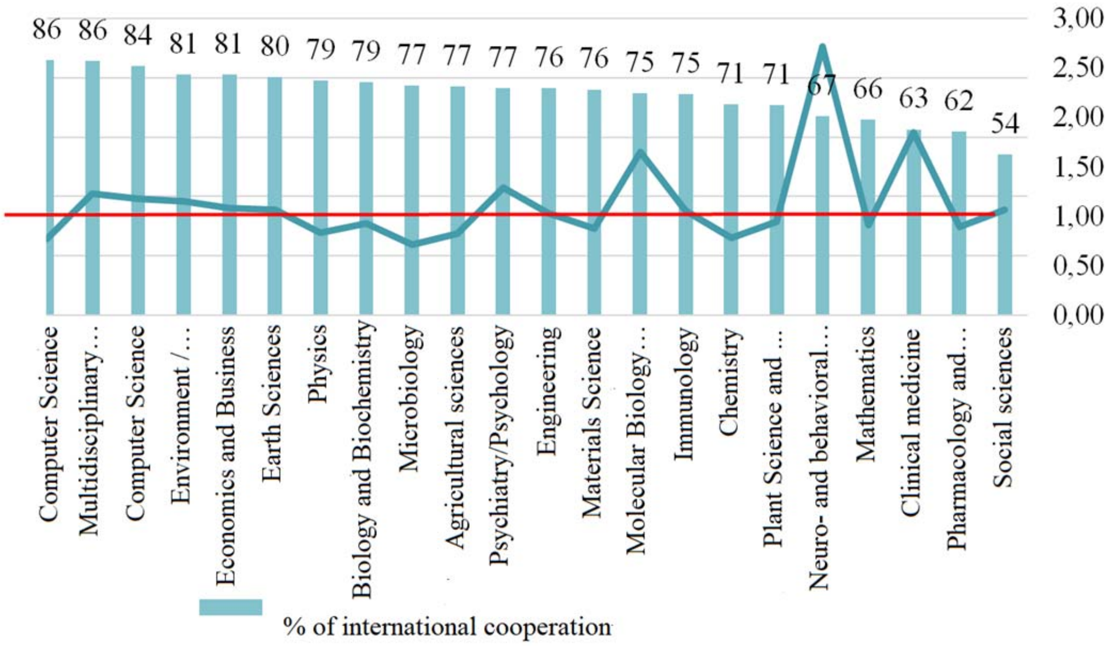
A country	2018–2020		2019–2021		2020–2022
Russia	35.9	↓	35.7	↓	34.9
USA	13.5	↓	12.4	↑	13.2
China	8.5	↑	10.7	↑	11.2
Great Britain	7.2	↑	7.6	↑	8.6
England	6.6	↑	6.9	↑	7.7
Poland	8.3	↓	7.9	↓	7.3
Germany	6.2	↑	6.8	↑	7.2
Türkiye	4.8	↑	5.6	↑	6.4
Ukraine	7.9	↓	7.2	↓	6.1
India	4.4	↑	5.3	↑	5.9

According to InCites (Clarivate Analytics), as of 02.06.2023.

Figure 6.59. Share of Kazakhstan's publications with leading partner countries by time periods. Top 10 by publications for 2020–2022

An analysis of three time periods of the top 10 countries for 2020–2022 shows a decrease in the intensity of cooperation with Russia in the last 2 periods. A similar trend is observed in Poland and Ukraine. Cooperation with the rest of the represented countries is growing.

The share of collaborations is most developed in such subject areas of Kazakhstani science as Space Science, Multidisciplinary Sciences, Computer Science, Environment / Ecology, Economics and Business, Earth Sciences, where 80% or more of the work in the database is represented in international cooperation (fig. 6.60).



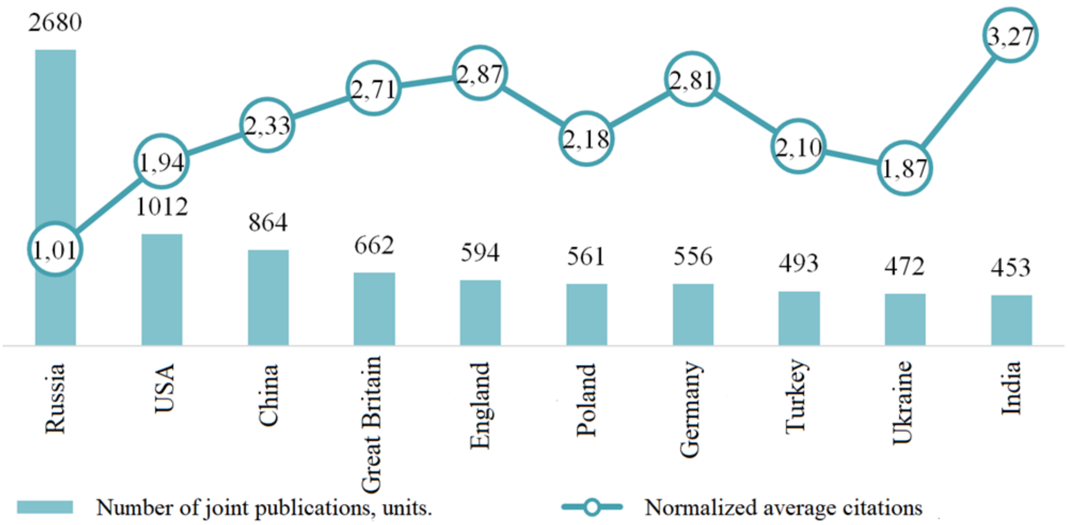
According to InCites (Clarivate Analytics), as of 02.06.2023.

Figure 6.60. Indicators of international cooperation of Kazakhstan by fields of science, 2020–2022.

The level of publication citation indicators is determined by the relevance and demand of the research. International publications generate greater interest in the scientific world and, accordingly, are cited more often. As you can see, the normalized average citation rate of works prepared in international collaboration in almost all of the considered fields of science has a value above the world average of 1.

In general, the works of domestic scientists for 2020–2022, created with foreign colleagues, have an average number of citations of 5,77, while publications prepared only by Kazakh authors – 1,72.

The normalized average citation rate of Kazakhstan is 1,02, the value of this indicator for publications with Russia is slightly less – 1,01; Ukraine – 1,87, with the USA – 1,94. For the top 10 countries under study, the highest values are for joint works with India, England, Germany and the UK (fig. 6.61).



According to InCites (Clarivate Analytics), 2020-2022, as of 02.06.2023.

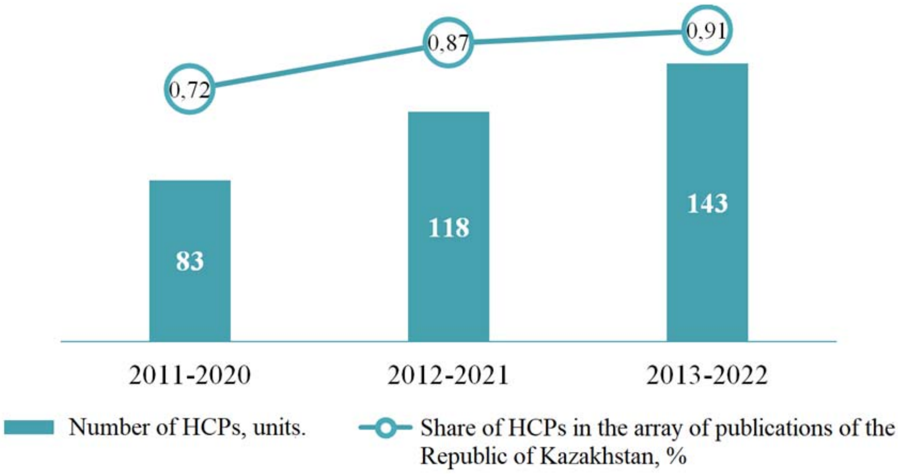
Figure 6.61. Bibliometric indicators of Kazakhstan with the top 10 countries by number of publications

Another citation indicator is highly cited publications in the Essential Science Indicators (HCP in ESI). Highly cited publications in the ESI are those that rank in the top one percent in a given year in each of the 22 subject categories represented in the Web of Science. For the calculation, publications over the last 10 years are taken.

Of the 143 TCPs in ESI for 2013–2022, 136 papers (>95%) were prepared in international collaboration. The observed increase in the number and share of HCPs in the total body of publications in the country indicates the fruitfulness of joint research (fig. 6.62).

Papers with high citation rates indicate high quality scientific research and can be used to assess the impact of publications compared to global averages in various subject categories. In the previous 2011–2020 and 2012–2021 periods, HCPs with Kazakhstani participation were presented in 19 and 20 thematic areas out of 22 – the Essential Science Indicators rubricator. For the studied years 2013–

2022, the HCPs has already covered 21 areas, with the exception of Multidisciplinary Sciences.



According to InCites Essential Science Indicators, as of 02.06.2023.
Figure 6.62. Dynamics of highly cited publications in Kazakhstan

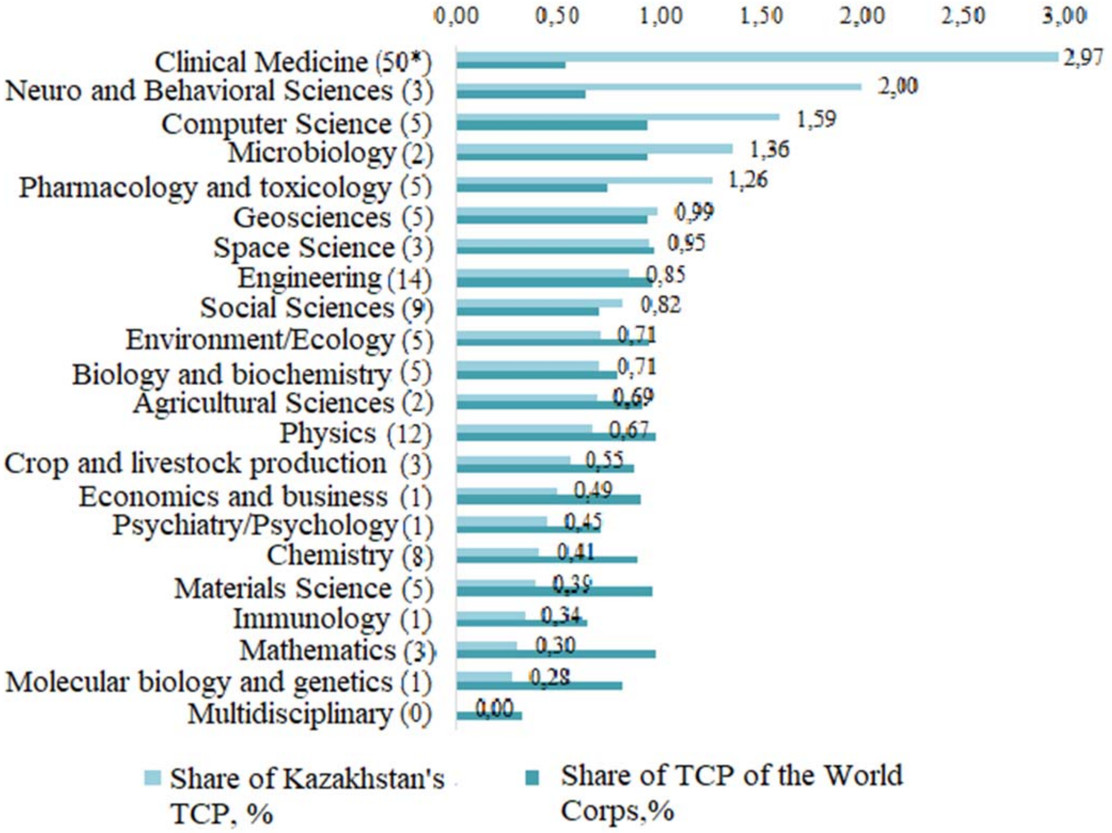
In the total array of highly cited publications in Kazakhstan for the period under study, there are 50 units. or 35% falls on the share of K clinical medicine. Engineering, physics, social sciences and chemistry provide another 30% of in-demand domestic publications. Biology and Biochemistry, Computer Science, Environment/Ecology, Geosciences, Materials Science, Pharmacology and Toxicology each have 5 HCPs; Mathematics, Neuro- and Behavioral Sciences, Crop and Livestock Science, Space Science - 3 each; Agricultural Sciences, Microbiology – 2 each; Economics and Business, Immunology, Molecular Biology and Genetics, Psychiatry/Psychology – 1 highly cited publication each.

A comparison of the distribution of HCPs by research areas shows that the share of HCPs in the Kazakhstan array exceeds the share in the global one - in 7 categories. This is clinical medicine with a HCP share of 2,97%, while the global figure is only 0,53%. Next come the neuro and behavioral sciences, computer sciences, microbiology, pharmacology and toxicology, earth sciences, social sciences. Obviously, international cooperation in these areas is the most effective (fig. 6.63).

In general, during the period under study, the share of highly cited works in the Kazakhstan array is higher than in the world – 0,91 and 0,77%.

The main scientific indicator of the popularity of an article in WoS and proof of a country's high achievements are *Hot Papers - hot articles* in the top 0,1% of the world ranking by citations over the past two years.

In the array of Kazakhstani publications for 2020–2022. 6 such works were identified, representing 5 areas of research, with the number of citations from 88 to 643 (as of 07.06.2023). All these publications were created as a result of the implementation of scientific and technical agreements with foreign and international scientific organizations.



* The number of HCPs of the Republic of Kazakhstan is given in parentheses
According to InCites (Clarivate Analytics), 2013–2022, as of 05.06.2023.
Figure 6.63. Distribution of highly cited publications by research area

The publication **in the field of neuro- and behavioral sciences** «*Global, regional, and national burden of stroke, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019*» , dedicated to research on the global, regional and national burden of stroke and its risk factors for 1990–2019. Regularly updated data on stroke and its pathological types, including data on incidence, prevalence, mortality, disability, risk factors and epidemiological trends, are important for informed stroke treatment planning and resource allocation. According to the 2019 study, the results of the assessment of general, as well as ischemic and hemorrhagic stroke are presented. It was shown that despite a significant decline in age-standardized rates, especially among people over 70 years of age, the annual number of strokes and deaths from stroke increased significantly from 1990 to 2019, with the fastest growing risk factor for stroke being high body mass index. It is concluded that without the urgent implementation of effective primary prevention strategies, the burden of stroke is likely to continue to increase worldwide, particularly in low-income countries.

The work was prepared by a team of scientists from 70 countries, including K. Davletov from KazNU named after Al-Farabi, published in the *Lancet Neurology* journal with an impact factor of 44,182, quartile Q1 in the *Clinical Neurology* category, cited 643 times.

Next in terms of the number of citations are 2 publications **in the field of clinical medicine**, created as part of international collaborations.

The article « *Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population–representative studies with 104 million participants*» was prepared as part of the NCD Risk Factor Collaboration (NCD-RisC) – Collaboration in the field of risk factors Noncommunicable Diseases (NCDs), which provides accurate and timely data on the main risk factors for NCDs for all countries around the world. The group of 1164 scientists from different countries included *B. Asembekov, K. Davletov, A. Dushpanova, Zh. Kalmataeva and A. Mereke* from KazNU named after Al-Farabi, *S. Berkinbaev* from KazNMU named after. S.D. Asfendiyarov, as well as *B. Zholdin* from West Kazakhstan Medical University named after M.Ospanov. A pooled analysis of 1201 representative studies involving 104 million people, the study examines global trends in the prevalence of hypertension and progress in treatment and control from 1990 to 2019. Published in the highly ranked *Lancet* journal with an impact factor of 79,323, Q1 quartile in the *Medicine, General & Internal category*, it has 490 citations.

Second article « *Cancer Incidence, Mortality, Years of Life Lost, Years Lived With Disability, and Disability - Adjusted Life Years for 29 Cancer Groups From 2010 to 2019 A Systematic Analysis for the Global Burden of Disease Study 2019* « prepared researchers from Global Burden of Disease 2019 Cancer Collaboration. Scientist *Sh. Bolla* (Nazarbayev University) took part in its preparation from the Kazakh side. It presents global cancer burden estimates and trends for 204 countries and territories by Sociodemographic Index (SDI) quintiles from 2010 to 2019. There was a global increase in the number of new cancer cases, cancer deaths, and disability-adjusted life years (DALYs) associated with cancer during the study period. The results of this systematic analysis suggest that the global burden of cancer is substantial and growing, with burden varying by SDI. The paper provides comprehensive and comparable estimates that have the potential to aid efforts to equitably control cancer worldwide. The work was published in the journal *Jama Oncology* with an impact factor of 33.012, quartile Q1 in the Oncology category, and has 234 citations.

In the field **of environment/ecology** in the category *Hot Papers* received the article « *Pharmaceutical pollution of the world 's rivers»*, presenting the results of a global study of pollution by active pharmaceutical ingredients (APIs) in 258 rivers of the world, their impact on the environment, 471,4 million people in 137 geographic regions. Samples were obtained from 1052 locations in 104 countries, covering all continents and 36 countries not previously tested for API contamination, and analyzed for the presence of 61 APIs. The highest cumulative API concentrations were observed in sub-Saharan Africa, South Asia and South America. It is concluded that pharmaceutical pollution poses a global threat to the environment and human health, as well as to the achievement of the United Nations Sustainable Development Goals. Scientists from Nazarbayev University and ENU named after Nazarbayev took part in the study. L.N. Gumilyov

B.Aubakirov and *R. Beisenov*. The article, published in the *Proceedings of the National Academy of Sciences of the United States of America* with an impact factor of 12,779, Q1 quartile in the *Multidisciplinary Sciences category*, has 206 citations in a year.

In the field of biology and biochemistry, the number of quickly cited review included the review « *Immunology of Acute and Chronic Wound Healing*», prepared by Nazarbayev University scientists *K. Razieva, E. Kim, Zh. Zharkinbekov, K. Kasymbek and A. Saparov,* together with a Japanese researcher from the University of Fukuoka. The paper discusses the role of innate and adaptive immunity in the pathogenesis of acute and chronic wounds, and examines novel immunomodulatory therapeutic strategies, including modification of macrophage phenotype, regulation of microRNA expression, and targeting pro- and anti-inflammatory factors to improve wound healing. Published in the journal *Biomolecules* with an impact factor of 4.879, quartile *Q* 2 in the *Biochemistry & Molecular Biology category*, the review has been cited 119 times.

In the field of physics, the list of the most popular works included the publication « *Enhancing active vibration control performances in a smart rotary sandwich thick nanostructure conveying viscous fluid flow by a PD controller*», dedicated to improving the performance of active vibration control in a thick multilayer nanostructure with an intelligent rotary engine transmitting flow viscous liquid using a proportional differential (PD) controller. The frequency characteristics of the cylindrical multilayer nanoshell are found to be significantly influenced by the geometry of the honeycomb core, the partial discharge controller, the fluid flow rate, the length-to-radius ratio (L/R), and the applied voltage. Another important consequence is that the use of a PD controller leads to an increase in the critical fluid flow rate in a smart nanostructure. The work was prepared by *D. Tazeddinova* from ZKATU named after Zhangir Khan together with scientists from China, Iran and Vietnam. Published in the journal *Waves in Random and Complex Media* with an impact factor of 4,051, Q2 quartile in the *Physics category, the Multidisciplinary* publication has 88 citations.

Thus, recently there has been some stabilization in the share of international cooperation between Kazakhstani scientists and researchers from other countries. The share of collaborations is most developed in such subject areas of Kazakhstani science as Space Science, Multidisciplinary and Computer Sciences. The main scientific partner of Kazakhstan is Russia, followed by the USA and China. The most popular among the top 10 countries are the results of cooperation with India, England and Germany. As a result of the fruitfulness of joint research, one can note an increase in the share of highly cited publications, the bulk of which were prepared in international cooperation. During the period under study, HCPs were represented in almost all thematic areas of the Essential Science Indicators rubricator, with the exception of Multidisciplinary Sciences. At the same time, more than a third of the HCP falls on the share of Clinical Medicine. As a result of the implementation of scientific and technical agreements with foreign and international scientific organizations in the array of Kazakh publications for 2020–

2022, 6 Hot Papers were identified - articles that over the past two years were in the top 0.1% in the world ranking by citations. International scientific and technical cooperation, allowing for joint development of scientific and technical problems, promotes the mutual exchange of scientific achievements, production experience, training of qualified personnel, and increasing the visibility of domestic research. International relations in the field of science, technology and education are accumulating potential for solving such important problems as achieving a level of development of science and technology that meets the needs of modern international society, which would improve the quality of national science and technology systems, as well as the training of qualified personnel for the national economy. International scientific cooperation is an important factor in the development of national science. The joint work of scientists stimulates the exchange of scientific knowledge and research skills, and allows access to unique scientific equipment, the full range of which cannot be afforded by any of the countries. The active interaction of the country's scientists with leading scientific centers is also an indirect sign of the level of national research recognized by the international community.

7. ANALYSIS OF THE DEVELOPMENT OF THE NATIONAL INNOVATION SYSTEM (through mechanisms of commercialization of technologies and results of scientific and (or) scientific and technical activities, integration of science, industry and business community, assessment of the contribution of science to the development of the country's economy and the impact of the results of scientific and (or) scientific and technical activities for the growth of gross domestic product)

Commercialization of the results of scientific and (or) scientific and technical activities (hereinafter referred to as RSSTA) in accordance with the Law of the Republic of Kazakhstan «On the commercialization of the results of scientific and (or) scientific and technical activities» (hereinafter referred to as the Law on Commercialization), along with scientific and educational activities, is a priority area of activity for scientific organizations and the organization of higher postgraduate education (OHPE).

To increase the potential and competitiveness of domestic science, there has been a significant increase in the volume of funding allocated for R&D from the state budget. According to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, domestic R&D expenditures from the state budget for the period from 2021 increased from 109,3 to 121,6 billion tenge in 2022. However, an increase in costs by more than 12 million tenge did not affect the science intensity of GDP, which in the reporting year decreased by 0,01% and amounted to 0,12%.

The operator for providing grant funding for RSSTA projects since 2016 is JSC Science Fund (hereinafter referred to as the Science Fund).

Financing of domestic science from the republican budget has almost doubled in the last two years. One of the measures to stimulate the commercialization of RSSTA is the provision of grant funding for these purposes.

Grant funding for RSSTA commercialization projects for 2020–2022 reached 11,876 million tenge: in 2020 - 5,400 million tenge, in 2021 - 4,860 million tenge, in 2022 - 1,616 million tenge.

At the end of 2022, based on the results of competitions for grant financing of RSSTA commercialization projects for 2016–2018. 140 high-tech industries were created, of which 15 projects were exported and 5 projects achieved sales of more than 1 billion tenge. Total sales revenue to date has reached 26,5 billion tenge, including exports – 465,5 million tenge. More than 6 billion tenge was paid to the budget in the form of tax payments. Co-financing amounted to about 6,8 billion tenge. More than 1400 jobs were created.

As part of the competition, held in 2022, 152 applications were submitted, of which 134 passed the examination. By decision of the specialized National Scientific Council for the commercialization of RSSTA, 72 projects were approved for funding, of which 68 contracts were concluded with grant recipients.

249 applications were attracted, of which 152 projects passed the formal examination stage.

The decision of the National Scientific Council (hereinafter referred to as the NSC) in the direction of « Commercialization of the results of scientific and (or) scientific and technical activities» identified 72 projects for concluding grant agreements for the commercialization of the results of scientific and (or) scientific and technical activities within the framework of the 2022 Competition. 68 agreements have been concluded with grant recipients, it is expected to create more than 300 jobs and attract co-financing in the amount of more than 900 million tenge.

According to the regional activity of grant recipients, the country's megacities are noted. In terms of the number of concluded contracts, Almaty is in the lead with 48,5%, Astana is in second place with 26,4%, and Shymkent is in third with 5,8%.

One agreement was concluded with grant recipients from the North Kazakhstan, Mangystau and Turkestan regions. There are no grant recipients from West Kazakhstan, Aktobe, Ulytau, Kostanay regions.

In terms of industries, the leading sectors among grant recipients are the agro-industrial complex and processing of agricultural raw materials 29%, the chemical industry 13,2% and mechanical engineering 10,2% (fig. 7.64).

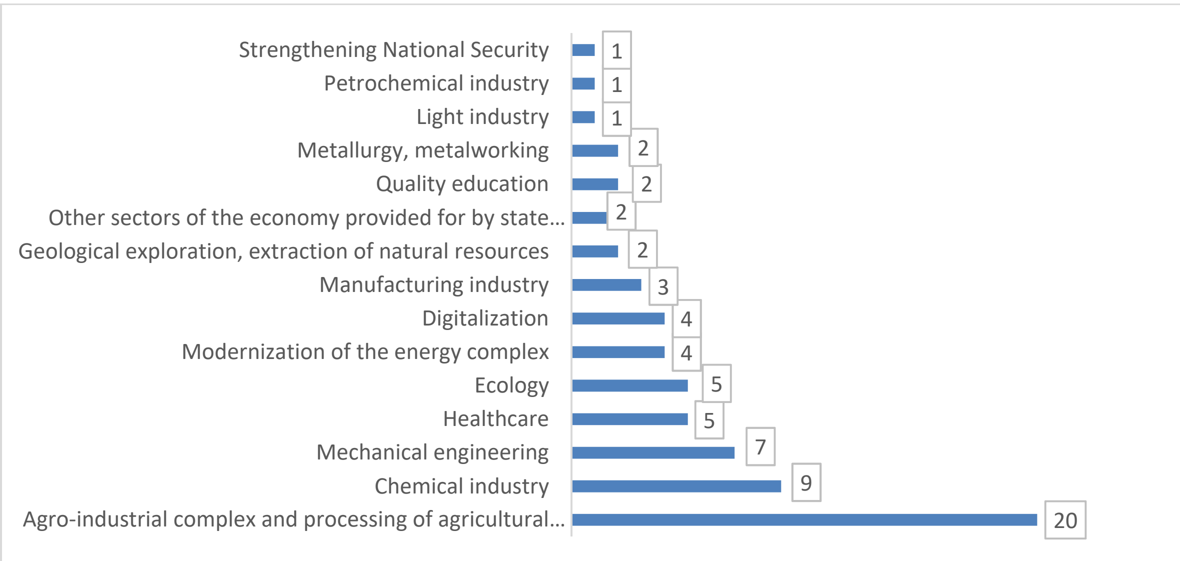


Figure 7.64. RSSTA commercialization projects by industry

325 new jobs were created as part of 68 projects. The ratio of men to women is 66:34. At the same time, 113 people, i.e. 35% are under 35 years old, 212 are over 36 years old, accounting for 65%.

Among the 325 members of the project teams, there are 35 doctors of science, 51 candidates of science, 25 PhD, 11 doctoral students, which is 11%, 15,6%, 7,6% and 3,3%, respectively.

In order to promote projects, a triple helix of interaction has been established: B2G, B2B, B2C. As part of the execution of the protocol instructions of the Interdepartmental Commission, 5 Roadmaps have been developed, work is being carried out with the Ministries of Agriculture, Health, Energy, Ecology and Natural

Resources, Industry and Infrastructure Development to implement the results of commercialization projects in industry production.

In order to establish interaction between representatives of science and the investment community and business entities, the Science Foundation has created the Business Partners Club - a community of business representatives interested in the commercialization of scientific projects. Currently, it includes 160 participants - 30 licensees, 100 business partners (investors and provision of material and technical base), 30 mentors.

As part of promoting the integration of science and business in 2022, the Science Foundation conducted 4 Commercialization Reactors within the framework of the Forum on Science Day on April 12, at Nazarbayev University on June 17, on September 22 on the basis of the Samruk-Kazyna National Welfare Fund and on October 31 at the NCE «Atameken». As a result of the events, 31 projects were presented, 12 submitted applications for the competition, 7 projects worth about 2 billion tenge were approved by the NSC.

Despite the measures taken to commercialize scientific developments, most of the results of applied scientific projects and programs are not in demand or are in little demand in the domestic economy, this is manifested by the low level of the ratio of commercialized projects to the total number of applied scientific research works. The dynamics of this ratio by year are reflected as follows: 2018 – 23.5%, 2019 – 20%, 2020 – 25%, 2021 – 26.1%.

With the adoption of the Law « On the Commercialization of the Results of Scientific and (or) Scientific and Technical Activities» , the share of universities that created RSSTA commercialization offices, technology parks, business incubators, and laboratories increased from 14% to 72%. However, it should be noted the weak level of activity of the RSSTA commercialization offices, endowment funds of universities and scientific organizations. This is due to the lack of specialists in the commercialization of RSSTA and the lack of competencies among scientists and specialists in the field of commercialization.

In addition, there is a trend of insufficient funding for RSSTA commercialization projects. For example, the number of received applications exceeds the number of approved RSSTA commercialization projects by an average of 8 times: in 2016, out of 337 applications, 32 projects were approved; in 2017, out of 502 applications, 83 applications were approved; in 2018, out of 447 applications, 78 applications were approved; in 2022, out of 152 applications, 68 were approved.

One of the main problems slowing down the implementation of strategic tasks in the field of development of science and commercialization of RSSTA is the weak interaction between science, business and production. First of all, this is caused by the disinterest of business in investing in science and the distrust of business in Kazakh science. As a result, a large number of R&D results are not in demand and are not implemented into production, and a large proportion of scientific results remain unrealized.

To achieve the intended goals, it is necessary to organize the coordinated work of scientific organizations and enterprises, create active platforms and interaction mechanisms, increase the share of development work in promising scientific areas: nuclear and hydrogen energy, digital technologies, artificial intelligence, biotechnology, biosafety, neuroscience.

In connection with this decision of the Government of the Republic of Kazakhstan dated February 14, 2023, the task was set to develop a new bill «On Science and Technology Policy» for Parliament, initiated by the President of the Republic of Kazakhstan K.K. Tokayev, to update the current Concept for the development of science, taking into account new mechanisms for the commercialization of results scientific research, as well as, together with the Atameken Chamber, organize work on the formation of specialized engineering centers and technology parks at leading universities and large enterprises of the country.

7-1. Analysis of the completeness of implementation of recommendations given following the approval of the National Report by the President of the Republic of Kazakhstan, assessment of progress in key areas of development of domestic science, results of foresight studies (with a frequency of 1 time in 3 years)

In 2022, in Kazakhstan, the number of enterprises carrying out research and development work amounted to 414 scientific organizations.

The number of scientific employees increased to 22 456 people. (2021 – 21 617), i.e. by 4%; of which 36,7 % (2021 – 33%) have an academic degree: 1743 people. – Doctors of Science, 3945 people. – Candidates of Science, 2460 people. – PhD doctors and 96 people. – doctors by profile.

In general, over the past period, indicators have improved in such scientific areas as materials science ; Science and Earth ; Mathematics, Physics, Engineering; Environment/Ecology, and more recently Social Sciences; Economics and business.

As a result, in 2022 the share of Kazakhstani publications in the flow of scientific information in the Web of Science Core Collection database increased. For 2020–2022 Kazakh scientists published 12536 (2021–12200) scientific articles, which allowed the country to maintain 76th place in the world ranking out of 213 countries for this indicator *(according to InCites, Clarivate Analytics). (For reference:* Russia – 15th place; Belarus – 91st; Armenia – 103rd; Kyrgyzstan – 131st*)*.

Funding for science from the republican budget has almost doubled in the last two years and in 2022 amounted to 121,6 billion tenge.

An analysis of internal R&D costs by funding sources shows that the state accounts for 82%, the own funds of scientific organizations - 28 %, and other sources – 8,6%.

In 2022, under the administration of 10 ministries, 132 programs were implemented - 100 based on 13 competitions and 32 based on 7 non-competitive applications. Within the framework of 10 competitions for grant funding, 1961 projects were implemented, of which 493 were completed, and the remaining 1468 were ongoing research projects.

The result of the implementation of research work in 2022 within the framework of program-targeted and grant funding was: 324 security documents; 7164 publications, of which 2965 are in foreign publications, including 878 in Web of Science and 1577 in Scopus; 423 implementation certificates were received for 158 implementations.

At the end of 2022, as a result of the commercialization of the results of scientific and scientific-technical activities, 140 high-tech industries were created, of which 15 projects were exported and 5 projects achieved sales of more than 1 billion tenge. Total sales revenue to date has reached 26,5 billion tenge. (in 2021 – 16,4 billion tons), including exports – 465,5 million tenge (in 2021 – 346,7 million tons). More than 6 billion tenge were paid to the budget in the form of tax payments (in 2021 – 5,2 billion tons). Co-financing amounted to about 6,8 billion tenge. (in 2021 – 5,2 billion tons).

As part of the Competition for the commercialization of the results of scientific and (or) scientific and technical activities in 2022, 68 agreements were concluded with grant recipients, it is expected to create more than 300 jobs and attract co-financing in the amount of more than 900 million tenge.

In 2022, enterprises of Kazakhstan produced innovative products worth 1 879,1 billion tenge, which is 3.9% (in 2021 – 3,4%) of the total industrial production of goods and services.

The total volume of innovative products sold amounted to 1 739,8 billion tenge, of which 286,3 billion tenge were exported. Innovation costs in 2022 amounted to more than 1 453 billion tenge, of which 7,6% were public investments.

In 2022, the following measures were taken to improve the situation in Kazakhstani science:

1. Strengthening the human resources potential of science and increasing the number of scientists by 1,5 times. As part of strengthening the human resources potential of science, the salaries of scientists have been increased by 2 times (up to 252 thousand tenge). Direct funding has been introduced for research institutes engaged in fundamental research.

2. Increasing the competitiveness of the scientific ecosystem. The modernization and institutional development of scientific organizations of the Science Committee has begun: more than 850 types of modern equipment have been purchased.

3. It is planned to increase the expenses of the business sector on R&D to 50% of total expenses, the share of commercialization projects to 30%, and an increase in patent activity by 30%.

4. Mechanisms have been introduced for the formation of priority scientific and technical tasks of industries (PTS), in accordance with the development priorities of the Republic of Kazakhstan.

5. Modernization of scientific infrastructure, interaction between science, business and production, development of commercialization and coordination of scientific and technological development.

The Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023–2029 was adopted, the goal of which is to increase the global competitiveness of Kazakh science and increase its contribution to solving applied problems at the national level.

Foresight research results

Priority I – «Rational use of water resources, flora and fauna, ecology»

In the field of animal resources, important are the issues of biological justification for the use, restoration of numbers and re-acclimatization of wild animal species, the ecosystem approach to the conservation of biodiversity; protection, restoration, conservation of rare and endangered species and animals listed in the Red Book of Kazakhstan; maintaining the Cadastre of fauna.

In the field of forest science, the following priorities should be formulated: scientific substantiation of new technologies for the conservation and propagation of forest species that are endangered and promising for practical use; long-term forecasting of the forest pyrological and forest pathological situation based on digital technologies.

Foresight research on the rational *use of plant resources* includes issues of identifying the species diversity of higher vascular plants in Kazakhstan and the development of the Herbarium collection fund; study of systematic features of groups of different taxonomic levels; a modern approach to identifying places of concentration of rare and endemic species; identification of key botanical areas; creation of regional, regional adastres , Red Books; thematic mapping, inventory and forecasting of the state of vegetation cover using remote sensing and GIS technologies; inventory and mapping of locations of alien and invasive plant species in Kazakhstan.

In the field of rational use of soil resources, priorities should be soil-geographical research for an objective understanding of the soil resources of Kazakhstan, monitoring the ecological state of the soil cover and predicting trends in its transformation in the face of anthropogenic and natural changes, soil quality and health.

In the field of ecology, research on conducting environmental monitoring and audit of both economic territorial sites and industrial territories using elements of artificial intelligence is of interest; development of waste recycling technologies and creation of a cycle of closed resource consumption; popularization of science in general and green technologies and stimulation of entrepreneurship in the field of environmentally friendly technologies and products in particular.

Future actions need to balance food security and conservation in the coming decades, including careful consideration and implementation of active land-saving strategies such as land use zoning, economic instruments (e.g. payments, land taxes and subsidies) and spatially strategic deployment of technology, infrastructure or agronomic knowledge, as well as standards/certification [10,92].

Priority II – «Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technologies, safe products and structures». In the field of new materials and technologies:

- it is necessary to develop alternative energy sources to increase the share of alternative energy in Kazakhstan to 30% of the total electricity supply by 2030;
- automated prediction of the internal structure of the collapse of an exploded complex structured block of a ledge during an explosion and the development of innovative technologies for ore mining without losses and dilution by 2026;
- development of technologies for the synthesis of nanomaterials (semiconductors, polymers, bio- and nanomaterials, composites, etc. and the opening of industrial production workshops in the field of nanotechnologies and nanomaterials by 2025 [114].

Priority III – «Energy and mechanical engineering». In the field of mechanical engineering

The greatest prospects are for the development of repair production in the railway industry and the mining and metallurgical complex, as well as the production of locomotives and wagons. There are prerequisites for mass production of cars and agricultural machinery.

World trends in the development of mechanical engineering science. The environmental factor will increase, and the efficiency of machines in terms of energy consumption and waste material emissions will increase significantly. The operation of machines should cause minimal harm to the environment. Consequently, the production of electric vehicles, wind energy sources, etc. will increase significantly. Scientific research in this area will expand, existing solutions will be improved and new directions will be created. In the field of technology for the production of machine parts, flexibility in the transition to new products will develop, in particular, the design of CNC machines will be improved, and new metal processing technologies will be created. The requirements for precision processing of parts will increase significantly. This is due to an increase in the speed of movement of machines and an increase in the influence of dynamic forces on the design of the machine. In the field of machine assembly technology, the development of robotic technologies is expected with the use of robotic autonomous equipment complexes, covering the entire assembly process from the component warehouse, assembly line to testing of finished products [117,131].

Priority IV – «Information, communication and space technologies»

Information and communication technologies. Foresight research should be the basis for determining the priorities of scientific and technological development of Kazakhstan. To solve the problem in the field of information and communication technologies, it is necessary to create our own aerospace technology with practical implementation in modern digital engineering production in Kazakhstan.

Space and aerospace technologies. Promising areas of research are the development of a satellite IoT service, radar and optical payloads for spacecraft, the possibility of creating balloons (stratospheric aircraft and lighter-than-air aircraft, etc.), technologies for studying deep and near space and other areas, foresight methods will continue to develop research in the space sector.

In order to develop fundamental and applied scientific research, the possibility of implementing the sixth Kazakhstan Program of scientific experiments on board the International Space Station will be explored.

Priority of V – «Scientific *research in the field of natural sciences»*

In the field of geography

The main strategic directions *of landscape research* in Kazakhstan: development of geographical foundations of landscape planning to solve strategic problems to ensure balanced land use and land management of the Republic of Kazakhstan and landscape and environmental requirements for the sustainable development of natural and economic systems of the Republic of Kazakhstan

The directions of fundamental research in *geomorphology* should be: study of the relationships between trends in global climate change and processes of exogeomorphogenesis; processes of geomorphogenesis in zones of intensive economic development (in rural and industrialized regions of the republic); ecological-geomorphological fundamental and applied research in different physical-geographical zones of Kazakhstan

To the main and promising studies *of the geography of tourism and recreation:* a comprehensive assessment and accounting of resources, opportunities and general trends in the development of all promising territories; development of projects for the effective use of tourism and recreational potential, increasing the efficiency and competitiveness of tourist complexes.

Breakthrough areas of scientific research *into hazardous natural processes* are developments in the field of ensuring safety from the effects of natural phenomena based on the assessment and mapping of natural hazards and risks [183].

In the field of mathematics

Machine learning is a field in which computers can independently learn from data and make predictions based on it. Modern mathematics is developing new machine learning algorithms that allow computers to obtain solutions in those problems, the analysis of which on the basis of mathematical modeling using the laws of nature is not yet possible.

The most important area in mathematics is the study of complex systems, such as social networks, economics, physics, biology, etc. This includes the development of new methods and tools, including extracting knowledge from huge amounts of data from biology, astronomy, the Internet and other sources based on new methods of mathematics, including mathematical statistics and machine learning. Closely related to the development of mathematical statistics is the theory of probability, which is used in many fields, including finance, economics, biology and physics. Developments in the field of cryptography, which is an important area in light of the growing need for data security, continue to be relevant. Modern mathematics is developing new methods of encryption and verification of cryptographic strength [205].

Priority VI – «Science of Life and Health»

In light of advances in genomics and molecular biology, the development of personalized medicine is expected. This will provide more accurate diagnoses, individualized treatment plans and optimized pharmacotherapy.

Biotechnology, including gene therapy, will play an increasingly significant role. The use of AI and machine learning will help improve the efficiency of management of medical facilities, as well as the development of individual treatment plans.

By 2030, active implementation of digital technologies is expected: electronic medical systems, telemedicine and networks for information exchange. Telemedicine will become an important part of the infrastructure, allowing you to receive quality medical services regardless of location.

Robotics and automation will become an integral part of medical and diagnostic processes.

The development and application of replaceable body parts, including endoprostheses and biografts, the use of 3D printing and other advanced design and manufacturing techniques provide the promise of creating customized solutions for each patient.

The use of nuclear medicine opens up new possibilities for precise diagnosis, treatment and research.

Big Data and predictive analytics will make it possible to analyze large amounts of population health data to identify patterns and optimize resources.

The widespread use of digital health systems and wearable devices will allow people to become more involved in managing their health.

The use of augmented and virtual reality technologies will improve the training of health professionals and clinical outcomes [205, 218].

Priority VII – «Research in Education and Science»

Projected future in education: the emergence of smart classrooms equipped with flexible and multi-touch displays; digital paper; robotic teachers who will teach lessons online. If we talk about the near future, we can note training using 3D printers. Another technology is *the Teacher – guide* (mentor). Teachers become guides, mentors and coaches, helping students learn new knowledge and skills. *Augmented reality.* In education, virtual and augmented reality can be used to enrich the learning process and increase student interest, which can change the functionality of textbooks. *Cloud computing.* Paper diaries are transformed into cloud documents.

Mobile classrooms and schools. There are already schools whose buildings can be assembled and disassembled like Lego, for example, the Australian MODUPOD. A mobile classroom is not only convenient and theoretically will help organize schools anywhere in the world and in the most unusual locations, but also develops ingenuity in its students.

Microlearning. This concept is an innovative approach to learning that allows users to gain knowledge and skills in small doses, tailored to their individual needs.

One of the main achievements obtained as a result of foresight research in Kazakhstan is the development of a national program for the development of languages in Kazakhstan. This program is aimed at the preservation and development of many linguistic peoples of Kazakhstan, including the Kazakh language. She also places special emphasis on teaching foreign languages, including English, Russian and Chinese [228].

Priority VIII – «Research in the field of social and human sciences»

Current problems of artificial intelligence, ontological status and axiological content of virtual reality, bio- and environmental ethics, media, interfaith and intercultural communication, etc. are promising.

There is a need to include in the subject area of philosophical, religious, and sociological studies the analysis of specific social cases and global dispositions that represent the multiplicity of forms and processes of modern transformations of man and society under the influence of virtualization and digital social practices.

Taking into account the specifics and possibilities of social knowledge (religious studies, sociology, political science), the innovative transformation of reality requires comprehensive research, long-term analytical projects related to monitoring the religious situation, the social well-being of citizens, political and civic activity, protest public sentiment and potential conflict-prone areas, the process transformation of social structure, formation of national identity and interethnic relations, etc.

Social sciences and humanities are called upon to warn society in advance about the difficulties awaiting it on the basis of reliable social forecasting [240,246].

Priority IX – «Sustainable development of the agro-industrial complex and safety of agricultural products»

About the main global technological trends and tendencies that will have the strongest impact on the development of the agro-industrial complex in the coming years:

1. Digital technologies. The main directions of digitalization of agriculture are related to reducing losses during cultivation, harvesting and storage, reducing the inappropriate use of working equipment, improving product quality through regular and rapid monitoring in livestock and farming, as well as the development of personalized marketing tools through automation and data management technologies.
2. Precision farming. Development of technologies: precision sowing and fertilization; precision irrigation; detection of diseases and pests, precise use of protective equipment. Automation of agrometeorological monitoring, mapping and crop yield forecasting. In the long term (more than 5 years) - self-controlled systems, unmanned heavy equipment, new energy sources.
3. Artificial Intelligence (AI). Research in the field of genomic AI is in its early stages, but its use has the potential to bring entirely new impetus and direction to many areas of science.

4. Nanotechnology coupled with AI and its integration into precision agriculture will play a vital role in exploring the design parameters of nanomaterials for use in the delivery of fertilizers and pesticides to ensure minimal impact on soil health, ensuring sustainable agriculture.

5. Agrobiotechnologies. Among the most significant technologies are genomic selection, new biotechnologies for plant protection and animal health, and the development of synthetic biology. Cultivation of microorganisms for targeted use for agricultural purposes. Genetic engineering in modern agricultural production is an integral part of the agrobiotechnological segment. Bioengineering is widely used in conjunction with biotechnology for the purpose of molecular design of compounds with specified properties (directed modification of proteins, directed evolution, engineering enzymology), for the development of genetically modified organisms, including agricultural plants and animals.

8. Switch to new food products. In the long term (over 5 years), a number of experts expect dramatic changes in the industry associated with the widespread dissemination of alternative technologies for producing traditional products - both food and feed.

9. Research to reduce greenhouse gas emissions. The agricultural sector's share of total global anthropogenic greenhouse gas emissions is approximately 13%, which is a significant proportion of the total. This figure is projected to increase by almost 40% by 2030, largely driven by increased demand from a growing population and changing dietary patterns, including increased demand for ruminant meat.

The listed areas of science contribute to the development of regenerative agriculture (Regenerative Agriculture, RegAg) in the Republic of Kazakhstan, in which environmental damage is minimized and potential returns are maximized. The strategy replaces «sustainable development», the most important environmental trend of our time, the goals of which are declared by the Republic of Kazakhstan and harmonized with the UN Sustainable Development Goals [306].

Priority X – «National security and defense»

Areas of foresight research in domestic military science include the following aspects:

– and research into network-centric, non-contact, hybrid and proxy wars, analysis of the forms and methods of using military and non-military forces and means in hybrid military conflicts, as well as waging war « by proxy» (proxy war);

– analysis and forecasting of the development of technologies for unmanned aerial, ground, surface and underwater vehicles, their integration with other systems, improvement of autonomy, as well as the possibility of using unmanned systems in various fields of military activity;

– and research and analysis of the use of various types of loitering ammunition, assessment of their effectiveness and capabilities in various conditions of military conflicts.

– and studying the experience of information wars and active propaganda in modern conflicts. Assessing the role of the media, the Internet and social networks in information warfare and developing methods of protection against their negative impact;

In the process of scientific research, the specifics of the Republic of Kazakhstan, its geopolitical and geostrategic position, national interests and resources must be taken into account. The research results can serve as the basis for developing strategic decisions in the field of military science, improving the country's defense capability and the effectiveness of military operations [341,343].

8. ANALYSIS OF THE ACTIVITIES OF INDUSTRY AUTHORIZED BODIES (on the management of science and scientific and technical activities)

8.1. Ministry of Health of the Republic of Kazakhstan

The total amount of funding for medical science in 2022 amounted to 13 456 million tenge, including the total amount of funds from the republican budget in 2022 – 12 755 million tenge and the amount of funds from foreign grantors – 701 124 thousand tenge.

For reference: *in 2022, medical universities and research institutes, scientific centers participated in the implementation of scientific and technical progress of program-targeted financing of the Ministry of Education and Science of the Republic of Kazakhstan with a funding volume of 4 570 million tenge, grant projects with a funding volume of 98 226 thousand tenge. At the expense of other domestic grant givers and funding organizations (National companies, business structures), in 2022, research programs and projects were carried out with a funding volume of 797, 749 thousand tenge. At the same time, representatives of the business community financing scientific research in the field of healthcare include 16 organizations from among Kazakh companies and representative offices of foreign companies in the Republic of Kazakhstan.*

At the expense of foreign grantors, in 2022, research programs and projects were carried out with a funding volume of 701 124 thousand tenge. Foreign grant givers and funding organizations include more than 20 organizations.

As part of self-financing from medical universities and scientific organizations, in 2022, initiative programs and projects were carried out with a funding volume of 197 903 thousand tenge.

Research Performance Indicators

There is an increase in the patent activity of medical science organizations and medical universities by 2.5% - the volume of annually received protection documents, amounting to 472 protection documents in 2022, including the number of national patents in 2022 amounted to 63, foreign patents - 9, certificates of intellectual property property – 400.

The leaders in the number of security documents received are the Higher School of Public Health, NJSC «West Kazakhstan Medical University» named after. M. Ospanova and the South Kazakhstan Medical Academy - these organizations account for 7,6%, 23,3% and 8% of all security documents received by organizations of medical science and education in 2022, respectively.

Over the past 3 years, the number of articles published annually by medical schools and health research organizations in publications indexed by Scopus and Web of Science has increased from 469 articles in 2020 to 817 articles in 2022.

The leader in the number of articles published in international peer-reviewed publications is the Kazakh National Medical University named after S.D. Asfendiyarov and Astana Medical University, which account for 19% and 11% of all articles published in international peer-reviewed publications in 2022.

Positive trends over the past 3 years are noted in the increase in the proportion of employees with the Hirsch index, according to WoS/Scopus and Google Scholar

- from 7,7% to 10,2% and from 10,7% to 21,5%, respectively, as well as growth of the average Hirsch index, according to WoS/Scopus – from 0,15 to 0,34.

The growth of all key indicators of the competitiveness of scientific and innovative activities made it possible to ensure the entry of Kazakhstani medical universities into authoritative global university rankings. Thus, at the end of 2022, the Kazakh National Medical University named after S. Asfendiyarov entered the TOP - 350 of the QS Asian University Rankings, in the TOP 150 of the ranking of universities for developing countries in Europe and Central Asia QS EECA (146th place).

8.2. Ministry of Agriculture of the Republic of Kazakhstan

The implementation of scientific and technical programs is carried out within the framework of the priority direction «Sustainable development of the agro-industrial complex and the safety of agricultural products» in 10 specialized scientific areas.

1. Development of livestock based on intensive technologies, the following results were obtained:

A new information system ApisLab has been developed, which is currently the only system in the republic for collecting, storing and processing primary breeding and zootechnical records of beekeeping. Selection and genetic parameters of the desired types have been developed in 12 basic camel breeding farms in 6 productive camel breeding zones. Based on the research results, 86 articles were published, including 1 monograph.

Priority 2. «Providing veterinary safety».

8 domestic vaccines, 13 diagnostics, 2 therapeutic drugs (for necrobacteriosis and streptococcosis of farm animals), national standard sera for diagnostic tests (for bovine leukemia, brucellosis, Newcastle disease, avian influenza), methods and schemes for disinfection and elimination of soil anthrax foci. 11 utility model patents received. Based on the research results, 52 articles were published.

Priority 3. Intensive farming and crop production (cereals, oilseeds, legumes, fodder, fruits and vegetables).

Genepool of agricultural crops. 237 samples were transferred to research and development works. 9 patents, 4 patent applications and 2 copyright certificates for admission of selection achievements to use were received. Published: 4 articles – Scopus; 1 – RSCI; 12 – CQAFSHE MES RK; 4 articles in journals and 26 abstracts in conference proceedings. In print: 1 article in Scopus; 6 – CQAFSHE MES RK.

Crop selection. The DNA bank has been replenished with 151 collections of grain crops (spring soft wheat, durum wheat, rice, barley). In various agro-ecological zones of the Republic of Kazakhstan, 2478 varieties of grains and legumes were studied and analyzed in the collection nursery. DNA identification of 60 collection chickpea samples (FLIPO9 nursery, ICARDA) was carried out using genes for resistance to Fusarium rot.

A working collection of 4510 varieties of oilseed crops and 250 varieties of cereal crops was studied. 24517 oilseed and 3000 cereal crops were studied in breeding nurseries. Hybridization was carried out on 5 oilseeds and 2 cereal crops, and hybrid seeds were obtained. 43 scientific papers have been published, including 5 articles in journals included in the Web of Science database, 15 in journals included in the CQAFSHE list, and 14 conference reports, 8 scientific articles in foreign journals, 8 patent applications have been filed.

Agriculture. In various agro-ecological zones of Kazakhstan, experimentally confirmed initial data on the scientific substantiation of the intensification of elements of farming systems were obtained. Profitability with the No-Till system was 176,3 and with the minimum tillage system – 185,6%. 57 articles published, incl. in foreign publications - 18, domestic - 39, 16 applications for protection documents were submitted .

Priority 4. Ensuring phytosanitary safety.

Scientifically based methods for predicting the spread have been developed: 4 limited distribution of quarantine pests on the territory of the Republic of Kazakhstan; 7 especially dangerous; 5 harmful organisms of agricultural crops. 13 scientific papers were published: 1 article with an impact factor, 2 articles in foreign journals, 4 articles in domestic publications, as well as 6 articles in the media, 1 patent for a utility model was received.

Priority 5. Processing and storage of agricultural products and raw materials. 13 technologies have been developed: 4 technologies and 2 recipes for export-oriented new types of meat products and canned food using plant raw materials and new food ingredients; 6 technologies for dairy and meat products, grain additives, 9 recipes for dairy, meat and bakery products, 1 recommendation for obtaining a new meat product with a reduction in the content of trans isomers using plant and animal raw materials.

1 production and experimental workshop for processing oilseeds was created on the basis of NJSC KazNARU. Based on the research results, 101 articles were published.

Priority 6. Sustainable development of rural areas. A methodology has been developed for an integrated assessment of the sustainable development of the region using demographic, economic, social, environmental and climatic indicators. Based on the research results, 8 articles were published and 7 intellectual property rights were obtained.

Priority 7. Effective sustainable management of natural resources in agriculture (land, pasture, water)

A database of space information on saline and wetlands has been designed, including cartographic material and satellite images. 17 scientific articles were published, incl. in publications, scientometric databases Scopus of Science – 2. 1 recommendation «Placement of fruit and berry crops and grapes in the fruit zones of Kazakhstan» was developed.

Priority 8. Organic agriculture. The influence of soil cultivation and the use of biofertilizers on the productivity of crops (cereals, oilseeds, etc.) under organic production conditions has been determined. Eight varieties of fruit and berry crops were selected for testing. A Concept has been developed for the formation and operation of the Register of Organic Seeds of Agricultural Crops in the Republic of Kazakhstan, and the organizational and economic conditions for the effective production and sale of organic products have been determined. 29 articles and abstracts were published, incl. 4 articles with a non-zero impact factor, 1 video film on organic production was shot.

Priority 9. Smart Agriculture. An economic analysis and assessment of the effectiveness of the use of information technologies in the production conditions of the Akmola region was carried out; with the introduction of a dispatch service, additional savings could amount to 36 250.8 thousand tenge, savings in current costs due to a reduction in diesel fuel consumption for production needs amounted to 2582 liters of diesel fuel or 503 490 tenge. 20 articles published, incl. 2 in foreign publications, 4 in CQAFSHE Ministry of Education and Science of the Republic of Kazakhstan.

In 7 basic herd horse breeding farms, 5 types of trackers were installed to assess the ethology of horses. A database has been created on objects of epidemiological significance for horse breeding farms. 10 publications have been published, of which: 4 - in CQAFSHE MES RK, 1 article - in the RSCI database, 4 articles - in collections of international scientific and practical conferences.

8.3. Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan

The Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan (hereinafter referred to as the Ministry of Labor and Social Protection of the Republic of Kazakhstan) is the administrator of the budget program 034 «Applied scientific research in the field of labor protection", the purpose of which is to increase the efficiency of state regulation of labor relations and labor protection based on the integration of science, education and production.

Within the framework of the priority scientific direction « Research in the field of social and human sciences» of the Ministry of Labor and Social Protection of the Republic of Kazakhstan, 3 scientific and technical programs (hereinafter referred to as STP) are being implemented, the executor of which is the Republican Research Institute for Occupational Safety and Health of the Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan (hereinafter – Institute):

1) STP *«Risk-oriented organizational and economic mechanisms for ensuring safe work in the conditions of modern Kazakhstan»* (implementation period 2021–2023), approved without competitive procedures by Decree of the Government of the Republic of Kazakhstan dated August 4 № 518, with a funding volume of 230 000 thousand tenge, including: in 2021 – 80 000 thousand tenge, in 2022 – 80 000 thousand tenge, in 2023 – 70 000 thousand tenge.

2) STP «*Economic problems of safe work and institutional transformations of the insurance mechanism in the Republic of Kazakhstan*”, financing of which for 2022–2024 is provided in the amount of 359 536 thousand tenge based on the decision of the All-Russian Scientific and Technical Committee dated March 14, 2022.

3) STP «*System modeling of the processes of formation and implementation of statistical observations of the state of labor protection in the Republic of Kazakhstan*» (implementation period 2022–2023) based on the decision of the HSTC with a funding volume of 113 228 thousand tenge.

The development of science in the field of occupational safety is seen in the example of the American model of industry development using the example of the National Institute for Occupational Safety and Health (NIOSH). NIOSH is a federal agency that conducts research and makes recommendations to prevent work-related injuries, illnesses and deaths. NIOSH employs professionals from a variety of disciplines and disciplines.

NIOSH has virtual centers, advisory centers, and a Board of Scientific Advisors. NIOSH informs about funding for its research and training programs by posting on the portal. This portal provides access to more than 1,000 grant programs offered by 26 federal grant agencies.

NIOSH's activities are structured in such a way that the federal institute works jointly to train personnel and conduct research with higher education institutions and manufacturing enterprises. Thus, NIOSH receives and implements not only new scientific projects and educational programs, but also trains industry specialists who have undergone real practice at the enterprise. The results of scientific research are used in the educational process. The most successful master's and doctoral students are employed in research institutes and their laboratories.

In connection with the above, it is proposed to adapt the American model, strengthening the status of the Republican Research Institute for Occupational Safety and Health of the Ministry of Labor and Social Protection of the Republic of Kazakhstan by opening a joint dissertation council and uniting, similar to NIOSH, with agreements, scattered departments of universities that produce specialists in the field of occupational safety and health.

8.4. Ministry of Digital Development, Innovation and Aerospace Industry of the Republic of Kazakhstan

Within the framework of the Republican budget program «Applied scientific research in the field of space activities» for 2021–2023, four targeted scientific and technical programs (hereinafter referred to as the Programs) are being implemented: two of them are being implemented with the stamp «FOU» (№ BR 109019/0221/PTF; (№ BR109018/0221/PTF) and two open Programs:

1. Creation of a national space situational awareness system: monitoring of near-Earth space, deep space and space weather.

2. Development of an expert decision support system in the space industry.

3. The program «Creation of a national system of space situational awareness: monitoring of near-Earth space, deep space and space weather» (hereinafter referred to as the SSA Program) will allow us to move to a new effective scientific and technical level of research. For Kazakhstan, as an operator and user of its own satellite constellations of the KazSat and KazEoSat series, planning the further assembly and operation of spacecraft, the presence of its own SSA system is of strategic and image importance.

Under the SSA Program Kazakhstan's multi-level space weather monitoring system is successfully developing. For the effective operation of this system in 2022, the following were created: a database for recording and storing geophysical parameters characterizing the state of near-Earth space (NES); web interface of the local database of neutron monitors and solar X-rays; software for calculating the disturbance index of the NES state.

Important practical results of the implementation of the Program SSA in 2022 was the commissioning of the best astroclimate observatory in Kazakhstan - the Assy-Turgen Observatory named after Academician of the National Academy of Sciences of the Republic of Kazakhstan T. Omarov: - An innovative spectral instrument (ISI) installed on the largest 1.5-meter telescope in Kazakhstan, AZT-20; – Wide-angle optical system (WOS), which uses the advanced achievements of world telescope construction.

4. The program «Development of an expert decision support system in the space industry» is a tool for tracking and analyzing the latest trends in science and technology. Based on a modular software architecture that allows flexible and customization according to the specific needs of the user.

Based on the results of the programs for 2022, 5 high-tech space technologies were developed. *Patents* were received for utility model № 6912 «On-board control complex for a spacecraft» and № 6922 «Power supply system for a spacecraft”.

The Ministry supported 21 projects aimed at commercializing scientific developments and implementing joint scientific projects with industrial partners, including 13 projects for senior and junior researchers, as well as 8 consortia in the manufacturing sector. The share of co-financing ranged from 10% to 30%. 150 jobs were created, 4 subprojects were successfully implemented. Thus, under the SRG/JRG program, one of the successful subprojects belongs to «Global Bee» LLP, which has developed a technology for introducing the reproduction of early cellular and cellular-free young bee colonies with specified characteristics for the development of beekeeping and increasing the productivity of bee apiaries. The commercialization of this subproject amounted to 46.5 million tenge or 80% of the grant amount. Also, under the MSC program, a subproject of the «EEN Group» LLP company was implemented, which developed a technology for increasing the service life of bimetallic spare parts cast on a steel basis. Commercialization of this subproject – 150 million tenge or 60% of the grant amount.

In 2022, **7** scientific and technical projects were completed (NJSC «Al-Farabi Kazakh National University», NJSC «Almaty University of Energy and Communications» named after G. Daukeev, LLP «STC ASKB Alatau», ENU named after L.N. Gumilyov for a total amount of 233 million tenge.

Research is aimed at developing: an effective encryption algorithm; a domestic product for searching for vulnerabilities in the machine code of telecommunication devices; means of cryptographic information protection.

Based on the research results, 24 works were published, including: 12 articles in scientific journals and periodical collections of international conferences included in the Scopus database; 2 chapters in the Springer collection; 10 articles in Kazakhstan scientific journals; 6 articles in journals and collections of proceedings of international conferences included in the RSCI database, as well as the Higher Attestation Commission of Georgia and Ukraine. 8 patents for inventions of the Republic of Kazakhstan and 2 copyright certificates for a computer program were received. Published 2 monographs, 8 articles in scientific journals of the CIS, received 4 patents for utility models.

8.5. Ministry of Culture and Sports of the Republic of Kazakhstan

The main directions of scientific work of the Ministry of Culture and Sports in 2022 were the study and research of objects of historical and cultural heritage through archaeological work, as well as conducting applied research on the study of tangible and intangible cultural heritage.

Archaeological research under the project *«Study of the Rakhat archaeological complex: reconstruction of history from the Bronze Age to the Late Middle Ages»* made it possible to identify new objects of historical and cultural heritage of this chronological period, on the basis of which the reconstruction of historical and ethno-sociocultural processes of migration, integration and assimilation in ancient times is carried out, determination of the degree and complexity of transformation of the material culture of the population of Zhetisu. The implementation of the project was accompanied by articles in the «Bulletin» of KazNU al-Farabi, in the collection of materials of the international conference.

The research work *«Paleographic factor in the formation of cultural genesis of the Nur - Ishim interfluve: features of house building and its evolution»,* implemented under the scientific guidance of the candidate of historical sciences A. Ganieva on the basis of historical and field archaeological materials, was aimed at studying the history of the development of construction and architecture stationary structures of the Kazakhs near modern Astana. The project gave a concrete idea of the features of the evolution of capital dwellings of the modern Kazakhs of the steppe Saryarka. Based on the research materials, 2 scientific articles were published in domestic publications, one article in a peer-reviewed journal, 1 article in the collection of an international conference and 1 article on the «History of Kazakhstan» portal.

During the implementation of the scientific project, scientific work was organized at the Institute of Oriental Studies named after Biruni of the Academy of Sciences of the Republic of Uzbekistan, at the National Library named after A. Navoi of the Republic of Uzbekistan, at the Research Institute of Humanities of Karakalpakstan of the Republic of Uzbekistan to identify materials on medieval cities, caravan sheds, routes, coming from Khiva, Urgench, Bukhara. The identified and published materials made it possible to reconstruct some aspects of the life and everyday life of the population of the Golden Horde.

During the implementation of the scientific project *«Archaeological monuments of the Akterek tract: issues of topography, typology and museumification»,* for the first time, a comprehensive study of the Zhetysu microregion - Akterek tract was carried out and the features and connections between archaeological monuments of different periods were identified. Based on the research results, a geomorphological and topographic map was compiled, a reconstruction of the ecosystem of the entire area was drawn up, and a scientific project was developed to create an archaeological open-air museum-reserve, which could become one of the attractive tourism sites.

The research work on the topic «*Structural features of the mounds of the early nomads of the Shelek-Talgar interfluve»* was aimed at the archaeological study of the funeral and memorial rituals of the ancient aristocracy of the Early Iron Age. The main source of study was the objects of historical and cultural heritage - the large mounds of Turgen and Ornek, which date back to the 5th - 15th centuries BC. The main result of the project can be considered the identification of the culture of «colored» mounds on the territory of this region, the presence of which has been proven through many years of research.

The continuation of the research program *«Archaeological scientific and experimental research at the Botai settlement and modeling of support systems, lifestyles and ideological and sacred contexts of the bearers of the Botai culture»* was due to the need to further develop knowledge about the contribution of the Botai culture as the matrix of the steppe civilization to world history and culture. During the archaeological field season of 2022, 224 sq.m. were explored at the Chalcolithic settlement of Botai. with three visually recorded housing structures, 3913 artifacts were extracted from bones, silicon, quartzite, lance, jasper quartzite, etc., which were inventoried and systematized; laboratory analysis of ceramics and osteology was carried out.

In 2022, the implementation of the scientific project was accompanied by the publication of 10 articles, of which 5 were in scientific publications, comparative studies of the traditional rituals of the Turkic-Mongolian peoples were carried out during scientific trips to Yakutia (RF), Mongolia and Turkey, a scientifically based concept of mass spectacular ethnographic holiday. The results obtained will find application in humanitarian (cultural, ethnographic) research, museum and educational practice.

Based on the results of all programs, 18 scientific articles were published in domestic publications, 2 in peer-reviewed journals, 8 in collections of international conferences, etc.

8.6. Ministry of Defense of the Republic of Kazakhstan

Scientific activities in the Ministry of Defense are carried out by higher military educational institutions (hereinafter – HMEIs of the Ministry of Defense of the Republic of Kazakhstan), as well as JSC «Center for Military Strategic Research» (hereinafter – CMVSR).

At the National Defense University named after the First President of the Republic of Kazakhstan - Elbasy (hereinafter referred to as the National Defense University), there is a military research center (hereinafter referred to as VNIC), which carries out research in the field of planning and use of the Armed Forces, the theory and practice of military art in training and conduct operations (conducting combat operations), weapons and military equipment, and other issues in the context of their use in the interests of the Armed Forces of the Republic of Kazakhstan (hereinafter referred to as the Armed Forces of the Republic of Kazakhstan).

High-tech laboratories operate on the basis of ERDC, incl. engineering and technical profile, scientific and technical information, information security (cyber range). A technology park has been created, the activities of which are aimed at developing the scientific and experimental potential of the National Defense University.

In 2022, higher educational institutions of the Ministry of Defense of the Republic of Kazakhstan, within the framework of basic funding in the interests of the Armed Forces of the Republic of Kazakhstan, completed 78 scientific research works, published more than 950 scientific articles (including about 80 in foreign publications), conducted 28 scientific - theoretical and scientific - practical conferences (intradepartmental, interuniversity and international) on current issues of military art, weapons and military equipment, problems of training and education.

At higher educational institutions of the Ministry of Defense of the Republic of Kazakhstan, more than 700 employees are engaged in research and teaching activities, of which 111 have academic degrees (10 Doctors of Science, 48 Candidates of Science and 53 Doctors of Philosophy (PhD).

In 2022, higher educational institutions of the Ministry of Defense of the Republic of Kazakhstan worked on 11 scientific projects within the framework of grant funding and 2 scientific and technical programs within the framework of program-targeted funding with a total funding amount of 973,2 million tenge. The implementation of these scientific projects and programs is carried out from 2020 to 2024, of which 2 scientific projects with grant funding were completed in 2022:
1. «Development of a new technical solution for creating a mobile device (ramp) for loading military equipment from a railway platform in unequipped places»

(2020–2022 in the amount of 58,5 million tenge). 2. «Creation of a prototype of a single-channel tropospheric station in the meter range» (2020–2022 - in the amount of 61 million tenge).

Another 11 scientific projects and programs remain in implementation, of which 9 are grant funding projects totaling:

1) 55,8 million tenge. 2) 44,3 million tenge. 3) 71,2 million tenge. 4) 18,9 ml tenge. 5. 53,9 million tenge. 6. 64,3 million tenge. 7. 43,2 million tenge. 8. 75,8 million tenge. 9. 33,6 million tenge.

And also 2 scientific and technical programs of program-targeted financing: 1) in the amount of 242,6 million tenge 2) in the amount of 150,1 million tenge.

As part of the implementation of the above scientific projects and programs, higher educational institutions of the Ministry of Defense of the Republic of Kazakhstan received 13 documents of protection and published 45 scientific articles.

Since 2022, CMSS has been implementing a scientific and technical program for program-targeted financing for 2022–2024 in the amount of 341,2 million tenge, the purpose of which is to create a military multifunctional educational platform based on advanced technologies, taking into account information security and processing of information that constitutes state secrets.

Thus, the total amount of funding for scientific projects and scientific and technical programs implemented in 2022 by higher educational institutions of the Ministry of Defense of the Republic of Kazakhstan and Central Military Research Institute amounted to 1 314.4 million tenge.

By the decision of the National Scientific Council dated November 24, 2022, funding was approved for application № AR15573960 «Production of domestically developed unmanned aircraft systems (UAS) for the needs of various areas of economic activity». This production is the production of UAVs for civilian use. The amount of financing for the entire duration of the project (2022–2024) is 232,2 million tenge.

8.7. Ministry of Energy of the Republic of Kazakhstan

In accordance with the Concept for the development of the fuel and energy complex of the Republic of Kazakhstan until 2030 (Resolution of the Government of the Republic of Kazakhstan dated June 28, 2014 № 724), one of the key tasks of the nuclear industry is the development of nuclear sciences.

Within the framework of subprogram 105 *«Applied scientific research of a technological nature in the field of nuclear energy»,* 4 targeted scientific and technical programs are being carried out.

The following main results were obtained:

− preliminary experimental data on the interaction of corium-facing material (first layer of composite protective coating) with aluminum oxide ceramics (second layer of composite protective coating) as a result of thermal effects;

− As part of the calculation justification for the decommissioning of the IGR reactor plant (hereinafter referred to as the IGR RF), assessments were made of the isotopic composition of the fuel and the radiation characteristics of active contamination of the structural elements of the IGR reactor plant (gamma radiation dose rates close to and at a distance of 1 m), as well as safe subcritical configurations of spent nuclear fuel during storage;

− Experimental data on the study of the interaction of tin-lithium eutectic (hereinafter referred to as TLE) with hydrogen isotopes at various levels of irradiation of research samples in a plasma beam installation with hydrogen and deuterium plasma. The results of the studies confirm the possibility of using tin-lithium eutectic in a thermonuclear reactor, and tin-lithium alloys can become a replacement for pure lithium, which in turn will simplify the solution of problems of ensuring tritium safety during the operation of future thermonuclear reactors;

− Preparations for reactor testing of an experimental device in the central experimental channel of the IGR reactor were carried out.

− Steel ingots were obtained from structural elements of experimental technological channels of a gas-cooled reactor for subsequent study of the efficiency of purification of radioactively contaminated metal. The research results will demonstrate the possibility of returning radioactively contaminated metal to useful use after its purification;

− Experiments were carried out to achieve the threshold for the occurrence of coherent optical radiation when excitation of gas mixtures in a pulsed nuclear reactor, as a result of which the spectral-luminescent and spectral-temporal characteristics of optical radiation were studied. The temperature dependence of radiation at the transition of an inert gas atom and alkali metal atoms, in particular lithium, has been studied;

Program «*Scientific and technical support for experimental research on the Kazakhstan materials science tokamak KTM*» is aimed at solving the urgent problem of providing experimental research on the KTM tokamak. As a result of the work performed under the program in 2022, the following main results were obtained:

− An experimental campaign was implemented on the KTM tokamak, which resulted in plasma discharges with a plasma current of about 500 kA and a discharge duration of up to 1 s, which is several times higher compared to the 2021 stage. New unique data were obtained on the formation of a KTM tokamak plasma cord with a vertically elongated cross-section in the ohmic heating mode, which will be used for further experiments on producing plasma and increasing its parameters, optimizing the plasma discharge scenario;

− Experimental studies were carried out to evaluate the preliminary operating modes of a gas-dynamic source (hereinafter referred to as GDS), adapted to the KTM tokamak. The results obtained will be used to install a control system for a gas-dynamic source of a molecular beam on the KTM tokamak for the purpose of supplying working fluids in the vacuum chamber of the KTM tokamak to implement the plasma replenishment and quenching scenario;

− Experimental work was carried out to study erosion and changes in the carbidized surface of tungsten, taking into account the irradiated temperature of the material, dose, density and energy of the ion flow. The concentration, electron temperature, ion flux and fluence of helium ions during tungsten irradiation were assessed;

− An experiment was conducted to test the cooling technique for a lithium divertor prototype (hereinafter referred to as the LDP) with a low-pressure vapor-gas mixture under bench conditions, as a result of which data on the operating modes of the LDP under bench conditions were obtained;

− A project for a radiation monitoring system for pulsed radiation from the KTM installation has been developed, taking into account previously obtained experimental data, which includes decisions on the selection of monitoring devices, their locations and integration into the information-measuring systems of the KTM complex.

Carrying out research under the program *«Development of comprehensive scientific research in the field of nuclear and radiation physics on the basis of Kazakhstan accelerator complexes»* is aimed at obtaining new experimental data for modeling processes occurring in nuclear power plants (fourth generation reactors, hybrid nuclear reactors, thermonuclear installations, etc.) .d.), as well as in the development of new technologies for the production of radioisotopes.

Under the program *«Development of nuclear physical methods and technologies for the innovative modernization of the economy of Kazakhstan»,* research is carried out on the development and implementation of nuclear medicine methods in clinical practice (in the diagnosis and treatment of cancer), nuclear physical methods for analyzing various objects, as well as radiation technologies for modification of the properties of substances, sterilization of medical devices, food processing, solving environmental problems, etc.

Based on the results of research in 2022, 42 scientific articles were published, 30 scientific developments were prepared, ready for use in the field of nuclear science and technology, 2 applications for patents of the Republic of Kazakhstan were filed.

The presence of competencies in the field of nuclear science and technology, radioecology, geophysics, thermonuclear energy, reactor materials science allows the Republic of Kazakhstan to be among those countries that are able to independently carry out work in fundamental and applied nuclear physics, nuclear and radiation technologies, and cooperate on equal terms with the most developed countries.

8.8. Ministry of Ecology and Natural Resources of the Republic of Kazakhstan

Within the framework of the priority scientific direction «Rational use of water resources, flora and fauna, ecology», 4 scientific and technical programs are being implemented:

1. Scientific and technical program «*Comprehensive assessment of the state of fish resources and other hydrobionts of the main fishing waters of Kazakhstan, and the development of scientifically based recommendations for their sustainable use»* with a funding volume of 1 805 969 400 tenge, including: in 2021 – 639 864 000 tenge, in 2022 – 612 742 800 tenge, in 2023 – 553 362 600 tenge.

Results obtained for 2022. The cost of aquatic biological resources in reservoirs was assessed, and 1 methodology was developed. Work on DNA libraries continued and sequencing of ddRAD markers (regional and population differentiation) began. An assessment of the number and structure, an analysis of the distribution of seals and identification of the most significant ones were carried out.

In 2022, it was planned to publish 32 scientific articles (including 2 articles in Web of Science/Scopus and 5 articles in CQAFSHE), 7 articles in the media, preparation of 6 recommendations, 1 atlas of seal rookeries, 1 method, registration of 5 implementation acts, 2 methodological tools, holding 5 seminars and obtaining 2 patents .

Additionally, 7 scientific articles were published *(*including 1 article in Scopus/Web of Science and 2 articles in CQAFSHE), 2 recommendations, 2 proposals, 2 manuals were prepared, 2 seminars were held, 21 publications in the media, 1 patent was received, 3 implementation certificates have been issued.

2. Scientific and technical program *«Scientific and technological support for the integrated development of aquaculture in Kazakhstan through the development and implementation of innovative technologies and new ones*» with a funding volume of 1 294 259 300 tenge, including: in 2021 – 439 705 000 tenge, in 2022 – 463 239 700 tenge, in 2023 – 391 314 600 tenge.

Results obtained for 2022. Standard technologies have been developed for the creation and operation of commercial lake farms, taking into account the regional conditions of each reservoir. The development of effective technologies for the formation of RBS of valuable rare fish species has continued. In 2022, it was planned to publish 25 scientific articles (including 2 articles in Web of Science/Scopus and 7 articles in CQAES), 13 articles in the media, conduct 4 seminars, obtain 3 patents, 1 act of implementation.

In addition, 4 additional scientific articles were published (CQAES), 1 patent was received, 3 applications for invention were filed, 1 seminar was held, 1 article was published in the media.

3. Scientific and technical program «*Cadastral assessment of the current ecological state of flora and plant resources of the Almaty region as a scientific basis for effective management of resource potential»* with a funding volume of 1 611 899 910 48 tenge, including:

in 2021 – 536 862 189 86 tenge, in 2022 – 536 489 664 23 tenge, in 2023 – 538 548 056 49 tenge.

Results obtained for 2022. An inventory of the species composition of flora and mycobiota was carried out for 6 administrative districts of the Almaty region and an annotated list of 6 administrative districts studied in 2022 was compiled, which is represented by 2133 species from 644 genera and 110 families. A collection of seeds of natural flora is being formed in a seed bank, numbering more than 4000 samples, which was replenished in 2022 by 403 seed samples. The program implementers published for 2022:

– 15 publications, of which: 2 articles – in highly rated international journals (Q1, 70% percentile); 1 article in the RSCI, 12 articles in materials of international scientific conferences;

– 1 act of transfer of work results and 1 copyright certificate for entering information into the State Register of Rights to Objects Protected by Copyright, № 28706 dated September 9, 2022 for the computer program: «Interactive map of the ecological state of flora and plant resources of the Almaty region";

– 4 catalogs of collection funds of living plants of state botanical gardens, which are used for scientific and educational purposes in KazNAU, KazNU named after Al-Farabi, KazNRTU, Medical University named after Asfendiyarov, as well as in environmental institutions.

4. Scientific and technical program *«Development of scientific foundations for preserving and increasing the sustainability of forest ecosystems in the regions of Kazakhstan»* with a funding volume of 947 712 382 70 tenge, including: in 2021 – 310 398 081 04 tenge, in 2022 – 321 777 948 42 tenge, in 2023 – 315 536 353 24 tenge.

Results obtained for 2022. 3 monographs were published, 14 certificates of implementation of research results into production were received (state forestry institutions of Almaty, Akmola, East Kazakhstan and West Kazakhstan regions).

5. Scientific and technical program «*Scientific assessment of the investment attractiveness of structures in Kazakhstan that are promising for identifying mineral deposits»* with a funding volume of 430 229 152 tenge, including: in 2021 – 139 256 318 tenge, in 2022 – 154 678 062 tenge, in 2023 year – 136 294 772 tenge.

Results obtained for 2022. As part of this global task and in accordance with calendar points 3 and 4 for 2022, a ranking of the geological structures of Kazakhstan was carried out using traditional and new mathematical techniques.

6. Scientific and technical program «*Micro and nanomineral components of ores as a resource for replenishing Kazakhstan's mineral reserves for the development of technologies for their development»* with a funding volume of 450 000 000 tenge, including: in 2021 – 150 000 000 tenge, in 2022 – 150 000 000 tenge, in 2023 – 150 000 000 tenge.

Results obtained for 2022. Collection and published materials on the second stage deposits were collected, analyzed and summarized: Bayankol (Konusny section), Kumdykol, Upper Irgiz, Koksu; ore occurrences of Northern Ulytau and technogenic deposits of the Mangistau Nuclear Power Plant (MNPP).

A methodological manual for the course «Nanomineralogy for students of geological specialties» has been prepared. The developer and main executor of this program is the Institute of Geological Sciences» named after K.I. Satpayev.

7 . Scientific and technical program *Heat-energy, mineral raw materials and medicinal and health-improving potential of thermo-mineral and industrial groundwater in Kazakhstan. Assessment of the state and trends in changes in hydrogeochemical parameters of groundwater under the influence of natural and climatic changes and anthropogenic loads* with a funding volume of 795 000 000 tenge, including: in 2021 – 264 977 997 25 tenge, in 2022 – 265 005 991 04 tenge, in 2023 – 265 016 011 71 tenge.

Results obtained for 2022. A geoinformation-analytical subsystem of thermomineral and industrial groundwater in Southern and Eastern Kazakhstan has been developed and created. The total length of route surveys is up to 40 000 km, 135 water points (wells and springs) were examined, 129 water samples were taken for chemical and 32 samples for isotope analyses. Additionally, surface waters, brine, bottom and salt deposits of 20 salt-bearing lakes were studied.

Based on materials from previously carried out work and expeditionary research carried out in 2022, 177 manifestations of medicinal mineral waters of 5 balneological groups were identified.

The developer and main executor of this program is the Institute of Hydrogeology and Geoecology» named after U.A. Ahmedsafin.

9. CONCLUSIONS AND SUGGESTIONS (on further development of the national scientific system)

Priority I – «Rational use of water resources, flora and fauna, ecology»

Conclusions. There is an acute problem of ensuring the country's water security, especially drinking water supply, preserving the natural balance of ecosystems, developing and measures for the rational extraction and use of benign groundwater of drinking quality.

In the development of research on the resources of flora and fauna, there is a tendency to study the influence of climate and anthropogenic impact on the disruption of ecosystems, reduction of habitats, reduction of biodiversity and extinction of species.

Research on the rational use of soil resources should be focused on the global problem of desertification and soil degradation, the search for techniques and methods for their restoration, and assessment of soil quality and health.

Environmental studies of the problems of the Aral Sea, wastewater disposal, and the impact of subsoil user enterprises on the environment remain relevant.

Analysis of the research results showed their fragmentation, lack of coordination, and integrity in research on this priority.

The lack of a unified strategy for the development of research work, ineffective interaction and the low level of development of cooperation between subjects of the scientific and technological chain are the result of the short-term nature of grants and projects won from time to time, their short-term nature due to including late opening of financing. This leads to the fact that the results of research work, which have not been brought to experimental development, contribute to a bias in funding towards research work to the detriment of development work.

Offers:

– for the implementation of large programs and projects of program-targeted financing in strategically important specialized scientific areas of scientific development, it is necessary to identify research institutes as the main implementers and coordinators;

– to provide for the creation of an analytical group, possibly under the National Academy of Sciences of the Republic of Kazakhstan, to process the results of research from research institutes, universities, etc. in order to determine priorities for the development of science, improve the quality of scientific research, systematize their results, plan innovative development, etc.;

– when forming scientific programs, targeted and grant funding programs, it is necessary to provide for research lasting at least 5 years, with a timely start of funding for research work from the beginning of the calendar year, which will increase their effectiveness;

– to modernize the infrastructure (modern material and technical equipment) of all research institutes of the Republic of Kazakhstan so that the infrastructure and laboratory equipment of all research institutes meet global standards, which will increase the effectiveness of Kazakhstani science as a whole.

Priority II – «Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technologies, safe products and structures». Under the section «New materials and technologies»

Conclusions. The research carried out is in accordance with the industrial policy of the Republic of Kazakhstan and is aimed at unlocking the industrial potential of the country. Fundamental developments in the field of new materials are of no small importance. Fundamental discoveries contribute to the advancement of materials science as a central science and lead to interdisciplinary results in such fields as chemistry, biology and physics, etc.

Offers:

– To support competitive scientific schools, introduce more widely the principle of competitive distribution of public finances;

– provide the research institute with the necessary modern equipment with the availability of its use by all scientists of Kazakhstan to increase the competitiveness of the research of Kazakh scientists;

– conduct joint seminars and webinars by scientists from various centers working in related fields to discuss new directions and the possibility of carrying out joint breakthrough research;

– create opportunities for closer scientific contacts with leading scientists of the world through internships for both young and leading scientists.

Priority III – «Energy and mechanical engineering»

In mechanical engineering

Conclusions. Currently Mechanical engineering in Kazakhstan is at the stage of development. Scientific research in this area requires a lot of material support, which includes machines, materials, premises, test benches, metrological support, etc. Mechanical engineering is a high-risk industry that requires large investments, competent, trained personnel, professional skills of workers, innovative developments, skillful management and marketing, etc. There is fierce competition for buyers in the mechanical engineering market, therefore, in order to obtain stable demand for your products, you need to constantly update them, as well as constant scientific research with a high commercial yield of innovative developments.

Offers:

It is necessary to change the examination procedure for obtaining scientific grants. Develop new criteria for assessing the effectiveness of the application. Entrust the carrying out of the examination to professional experts, citizens of the Republic of Kazakhstan, specialists who are sufficiently competent in their field. An expert must be specially trained, and his work must be adequately paid. Grants should be allocated to those who have a new solution that has the prospect of implementation and usefulness for the business. The result of the grant should be an objective positive result, and not an article in the international Scopus database.

The main criterion for a positive assessment is the presence of a noticeable new technical solution, the use of the most modern scientific equipment - mathematical methods, computer programs, etc. At the commercialization stage, private venture firms with their own capital should work. They should have preferences: at the implementation stage, they should be exempt from taxes, receive subsidies from the state, as well as part of the patent rights to intellectual property.

Priority IV – «Information, communication and space technologies»

Conclusions. The process of digital transformation of public services is in full swing in the country, but this process has so far barely affected industrial enterprises and educational institutions. Information and communication technologies are developing, but almost half of the territory of Kazakhstan is not yet covered by mobile communications and the Internet.

Despite the presence of existing infrastructure in Kazakhstan, there is no industrial base for telecommunications and space technologies. There are no results of experimental design (R&D) and technological research in the rocket and space industry, without which the advancement of technology and the development of industrial production, including aerospace technology, is practically impossible.

The current state of development of the scientific, technological and aerospace complex of Kazakhstan is characterized by the following features:

– the chains of creating innovative products in Kazakhstan are open: fundamental research does not turn into applied research, applied research into R&D (not funded in Kazakhstan), and the latter into industrial products;

– there is a need for personnel with appropriate qualifications (for initiating innovations and R&D, mastering complex technological processes and new products), a serious shortage (especially of designers and mechanical engineering technologists) of which is observed in almost all industries. Often, personnel trained abroad are not adapted to Kazakh working conditions;

– despite significant funds recently allocated for the purchase of equipment at the level of world standards, constant modernization of the instrument fleet of the R&D sector is necessary;

– large, economically wealthy enterprises with sufficient financial, human and intellectual resources are most inclined towards innovation, while all over the world small enterprises play an important role in intensifying innovation processes, which is due to their initiative, flexibility, and ability to quickly adapt to new requirements;

– enterprises in almost all industries prefer purchasing ready-made technologies, machines and equipment to other innovations.

– due to the low technological level of the production base, it is impossible to manufacture many types of high-tech industrial products, for which there is high demand in the market . As a result, dependence on foreign supplies of finished products increases, which makes it possible to partially or fully compensate for the lack of domestic industrial production.

A significant feature of the technological development of Kazakhstan today is precisely the fact that the technology market lacks solutions necessary for business. On the one hand, the R&D sector cannot satisfy the existing high demand of companies for new high-tech solutions in certain areas, on the other hand, technologies developed with government funding largely do not correspond to the structure of real requests from companies and the international market.

Offers:

– carry out a digital transformation of the country's economy, primarily industrial enterprises and the field of vocational education;

– use aerostatic aircraft along with spacecraft to implement the digital transformation program;

– use, along with spacecraft, more accessible and feasible technologies in Kazakhstan: this is the use of tethered aerostatic aircraft for various functional tasks at an altitude of one to 10 km (optimal altitude 3000 m).

The use of tethered aerostatic aircraft will allow:

– perform stationary round-the-clock, year-round remote monitoring of a given area of the Earth in the optical, infrared and radio ranges;

– ensure stable operation of telecommunications, Wi Fi, 5G, 6G, mobile and radio communications, the Internet;

– ensure the operation of an autonomous navigation system;

– ensure stable operation of target equipment during the digital transformation of industrial enterprises and when conducting scientific and technical research in the Earth's atmosphere in digital format.

It is extremely important to create the technological foundations for the digital transformation of mechanical engineering production of promising aerospace systems.

Priority V* – «Scientific *research in the field of natural sciences». Section «Fundamental Research in Geography»

Conclusion. To realize the possibility of conducting high-quality fundamental geographical research, it is not enough to assign universities the status of research universities. It is necessary to strengthen and modernize the equipment of research and university centers with a geographic profile.

To organize and carry out fundamental geographical research, it is necessary to improve the professional level of specialists with knowledge of higher mathematics and systems analysis and to revise educational programs at all levels of education.

To develop the scientific, technical and human resources potential of geographers, it is desirable to participate in research work on international projects; obtaining international certificates and training young geographers through PhD programs at leading universities in Germany, Great Britain, and Switzerland.

Suggestions:

– revise educational programs at all levels in geography to develop geosystem thinking and the ability to understand mathematical models and the ability to use their computer versions;

– equip universities with modern research tools, incl. to develop new technologies for solving environmental problems;

– to organize courses on familiarization with foresight technology, to build a logical scheme for the interaction of all areas of fundamental scientific research with access to the specific needs of business and the state in accordance with foresight technology.

Fundamental and applied research in mathematics

Conclusions. Mathematics is the basis for many other scientific and technical fields, and plays a key role in the development of new technologies, computer science, engineering, physics, economics and many other disciplines.

Publishing the results of mathematical research in articles is an important and widespread practice in the academic community of mathematicians, facilitating the exchange of knowledge, discussion of results, and stimulating further development of mathematics. Moreover, the publication of articles is part of the system for assessing the scientific productivity of a mathematician.

A total of 6 992 968 articles or reviews (Review Article or Article) were published worldwide in 2020–2022 in journals indexed by the Web of Science Core Collection with an impact factor. Kazakhstan occupies 76th position in this list with 6820 publications. The gap from 50th place (Nigeria, 22 578 articles or reviews) is 3,31 times.

If we compare such publications in the field of research « Mathematics», then a total of 243 858 articles or reviews have been published worldwide. Mathematicians of Kazakhstan have published 473 rating works and according to this indicator Kazakhstan is in 63rd position. The gap from 50th place (Ukraine, 1028 articles or reviews) is 2,17 times.

Considering that the growth rate of the number of rating publications in Kazakhstan is much higher than the growth rate in the world, one can set a realistic goal for the next decade to include Kazakhstani mathematics in the Top 50 countries by the number of articles or reviews in journals indexed by the Web of Science Core Collection with an impact factor. To achieve this goal, it is necessary to significantly increase (two to three times) the number of mathematicians actively working in science.

Offers:

By significantly increasing the number of mathematicians actively working in science, achieve at least a twofold increase in the number of rating publications of Kazakh mathematicians, maintaining as a priority the importance of:

– scientific content of publications;
– level of rating publications;
– number of rating publications;
– growth rate of the number of rating publications.

Priority VI – «Life and Health Sciences»

Conclusions. The current state of research activity (R&A) in medicine in Kazakhstan is reflected in the positive dynamics of its indicators: there is an annual increase in R&D funding, an increase in the number and quality of ongoing scientific projects, scientific products in the form of publications in high-ranking international journals, obtaining protection documents, and an increase in the H-index scientists and citation rates of scientific publications. However, there is a problem of a shortage of scientific personnel in medical science and a decrease in their stature, poor integration into international cooperation and participation in joint projects, a lack of infrastructure and equipment for conducting research that meets international standards and trends.

Offers:

Review the financing of medical science (increase the PTF, attracting 1% of the income of subsoil users).

Fund applied research aimed at creating innovative solutions to problems relevant to the economy of Kazakhstan (5-year period).

Strengthen human resources potential in medical science: motivating young specialists, expanding personnel training, attracting leading medical research institutes and scientific centers, postdoctoral programs and training abroad.

Improve the infrastructure and equipment of scientific organizations for cooperation with foreign centers.

Create an international scientific and educational center on the basis of the KSCDID of the Ministry of Health of the Republic of Kazakhstan with the participation of the National Academy of Sciences of the Republic of Kazakhstan and international organizations to train specialists in the fight against diseases.

Support the internalization of research projects.

Create a national platform for the application of scientific knowledge (Knowledge Translation Platform, Knowledge4Policy - K4P) to disseminate the research results of Kazakh scientists among healthcare professionals and managers in policy-making.

Priority VII – «Research in Education and Science»

Conclusions. Significant advances have been made in science education through the introduction of educational innovations, lifelong learning, technological, methodological and pedagogical advances, the promotion of critical thinking, applied, self-regulated and collaborative learning. These innovative teaching methods help develop a new generation that is better prepared to face the challenges of the 21st century. There are natural areas of need for learning systems to use digital resources.

Offers:

Strengthen cooperation between domestic scientists and foreign partners;

In scientific publications devoted to education and linguistics, cover more global and broader topics; and to intensify the work of Kazakhstani scientific schools;

o discuss the problem of introducing pedagogical residency/internship.

Priority VIII – «Research in the field of social and human sciences»

Conclusions. The priority areas of social and humanitarian research in Kazakhstan are problems of interaction between ethnic groups and faiths, cultural identity and diversity, cultural heritage, history, memory and social justice, as well as the search and development of new scientific paradigms, a methodological platform for structuring research activities in the field of humanities .

Offers:

Conduct a comprehensive study of the problems of ensuring national security using the advantages of sociological, religious studies, political science and other methodology in order to develop proposals and recommendations for stabilizing and managing various negative processes (radicalization of mass consciousness, social stratification, migration, protests and conflict-prone areas of social life, etc.), minimizing their consequences and finding ways to neutralize them;

To implement, within the framework of the political science discourse of strategic planning and development of methodological foundations for ensuring the policy of implementing the «Zhana Kazakhstan» course, with the involvement of all interested participants - entrepreneurs, politicians and the population, etc.;

Create a digital database of sociological and religious studies with open access for researchers, scientific and educational institutions, for the purposes of long-term monitoring and forecasting of transformations of public consciousness, increasing the validity of the results of applied social analysis and ensuring their translation into specific socio-political technologies and targeted scientific - practical recommendations.

Priority IX – «Sustainable development of the agro-industrial complex and safety of agricultural products»

Conclusions. Analysis of the information presented shows that significant high-level results are generated by scientific groups of domestic scientists using modern methods and approaches to research in close collaboration with leading scientific centers, universities and organizations.

Agricultural science is becoming more and more complex, in conditions of rapid variability of factors (inconsistency of production and supply conditions), a deep understanding and clear representation of processes in kinetics is necessary, and therefore it is important to introduce new approaches, methods and technologies into ongoing and planned scientific research, to increase the requirements to their effectiveness in solving applied problems in the agro-industrial complex.

Offers:

1. Create a system of independent formulation of scientific problems based on the results of periodic foresight research, technology scouting, constant analysis of current industry needs and forecasting. Such a system should be organized under the line ministry, for this priority area - in the Ministry of Agriculture of the Republic of Kazakhstan.

2. Increase funding for agricultural science to at least 1% of the GDP of the agro-industrial complex. Ensure the implementation of an inter- and transdisciplinary approach in organizing scientific research by introducing appropriate conditions into the technical documentation of program-targeted and grant funding of scientific and technical programs and projects.

3. To solve strategically important problems, provide an instrument for financing integrated, targeted national programs, following the example of the Strategic Program «Designing the Wheat of the Future", funded by the Biotechnology and Biological Sciences Research Council (BBSRC) of the UK Government.

4. In order to accelerate the development of scientific collaboration between domestic and foreign scientific organizations, provide an instrument for financing research cooperation programs following the example of the US Department of Agriculture, supporting joint research and educational projects between specialists from the United States and other countries in the field of agriculture farms.

Priority X – «National security and defense»

Conclusions. In the period from 2020 to 2022, Kazakh military science continued to develop, which was largely facilitated by the build-up of military scientific potential, the attraction of novice military and non-military scientists, research teams, as well as international military cooperation.

At the same time, in 2020–2022. Some problematic issues also came to light:

– for a long time, at the state level, the mechanism for concentrating efforts and mobilizing scientific potential to conduct relevant research in the field of ensuring the national and military security of the state was not worked out;

– at the enterprises of the defense industry, in the Armed Forces, other troops and military formations of the Republic of Kazakhstan, the scientific and experimental base for conducting research is insufficiently developed;

– insufficient level of R&D funding. The creation of new production facilities and the introduction of new technologies is not always supported by preliminary R&D.

Offers:

Explore the possibilities of organizing a full cycle of research and development activities for the development of weapons, military and special equipment, as well as their modernization. Pay more attention to the activities of subordinate research, as well as scientific and production organizations and design teams at defense enterprises.

Particular attention should be paid to the creation/improvement of the scientific and experimental base at defense industry enterprises, in secondary and higher military educational institutions of the Republic of Kazakhstan, as well as in military departments of civilian universities. In addition, it is advisable for law enforcement agencies to develop incentives for scientific, inventive and rationalization work.

Achieve sustainable funding for R&D, including in the interests of developing a scientific and experimental base, introducing innovative technologies for the production of military products, and justifying it by mandatory preliminary R&D.

Military and military-technical cooperation with foreign partners in joint scientific projects must be linked with leading military universities through educational and scientific-technological exchange.

Currently, much attention is being paid to Kazakhstani science : specific areas of unprecedented state support in the political, organizational, legislative, regulatory and financial-economic spheres have been identified. This is required by modern realities associated with the reduction of life support resources, with the need to develop domestic science to overcome these problems in order to achieve sustainable rates of economic development, preserve national sovereignty and the quality of life of the population of the republic.

The system for managing the scientific potential of Kazakhstan should facilitate research that corresponds to the world level and the active promotion of the most advanced developments existing in developed countries in the world. At the same time, the vast majority of research should be aimed at solving specific scientific and practical problems and have pragmatic goals set by the state and society. We should strive to transform knowledge into innovation and technology.

In connection with the assigned tasks, an analysis of the current situation in science was carried out, and the ways of forming scientific and innovation policy were revised. The Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023–2029 has been developed, the goal of which is to increase the global competitiveness of Kazakhstani science and increase its contribution to solving applied problems at the national level, plans to gradually increase R&D costs from all sources to 1% of GDP.

In order to revise the strategic approach to the formation of scientific and innovation policy, synchronized with the economic policy of the state as a whole, the National Council on Science and Technology under the President of the Republic of Kazakhstan was created, which included scientists representing priority areas of science, having a high level of research activity and international confession. Work is underway to develop a new Law «On Science and Technology Policy».

All measures taken to formulate scientific and innovation policy will serve to increase the effectiveness of Kazakhstani science aimed at developing the country’s economy.

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11. GLOSSARY

Axiology (from the Greek ἀξία - value and λόγος - doctrine) is a philosophical discipline that studies the category of «value», characteristics, structures and hierarchies of the value world, methods of knowing it and its ontological status, as well as the nature and specificity of value judgments.

Bifurcation – change in the nature of motion of a dynamic system over a large time interval when one or more parameters change.

Venomics is a branch of proteomics that studies the protein composition of venoms of various animals.

Virtual object – data in digital format, stored on electronic media and accessible as an object of substantive activity in offline or online mode using special technical means of information processing.

The military doctrine of the Republic of Kazakhstan is a system of views officially adopted in the state on ensuring the military security and defense of the Republic of Kazakhstan. Taking into account military threats, it identifies priority areas of state activity in the military-political, military-strategic and military-economic spheres, for the mobilization preparation of the state, as well as measures for the development of the military organization of the Republic of Kazakhstan.

GWAS (genome - wide association studies) is a genome-wide association search for the purpose of identifying genetic risk factors in order to provide an informed prediction of susceptibility to disease, as well as identifying the biological basis of susceptibility to disease in order to develop new prevention and treatment strategies.

Hybrid war (eng. hybridwarfare) is a form of military conflict that includes a combination of guerrilla and civil wars, insurgency and terrorism. Represents any action by an adversary who instantly and coordinately uses a complex combination of legal weapons, guerrilla warfare, terrorism, and criminal behavior on the battlefield to achieve political goals.

Humanitarianization of the information society is a process that results from the involvement of broad sections of the population in the use of information technologies; characterized by the humanitarization of the technological component, i.e. extending it to areas related to problems of humanity, involving it in solving universal human problems.

Dialog box – a program (application) window in which the user sets parameters and provides information necessary to perform certain operations of the application.

Dual (or practice-oriented) training is a form of training that provides for obtaining not only theoretical knowledge in the process of mastering educational programs in an educational institution, but also practical knowledge, skills and abilities in real production.

Immersive technologies (immersive - immerse) - technologies for full or partial immersion in the virtual world or various types of mixing the virtual world and reality. Augmented reality (AR) and virtual reality (VR) are two main types of immersive technologies.

ICT competence is the personal ability of a specialist to solve a class of professional problems associated with the use of information and communication technologies in their professional activities.

in vitro – a technique for performing experiments «in vitro» in artificial conditions, outside the body or natural environment.

Interactivity is the ability of an information and communication system, without human intervention, to actively and variedly respond to user actions.

User Interface – general principles of communication between the user and the program; appearance of the program dialog box, which contains control panels and user menus.

Information technologies are highly efficient modern technologies for working with information, i.e. collection, accumulation, storage, search, processing and issuance information necessary for information support of activities.

An influencer is an opinion leader around whom a loyal audience gathers. Most often, the influencer is also a blogger and interacts with his audience through social networks (Instagram, YouTube, TikTok).

Artificial intelligence is the property of intelligent systems to perform creative functions that are traditionally considered the prerogative of humans; the science and technology of creating intelligent machines, especially intelligent computer programs.

Comparative studies (Latin comparativus «comparative») is a comparative historical method and an independent scientific discipline. The comparative method is understood as a way of understanding the surrounding world, which is based on the use of the comparative historical method, the method of analogy, etc.

Health (mobile health) refers to program interventions aimed at preventing, managing or treating disease.

Medtech (medical technology) is medical technology used to improve the quality of life and to diagnose, monitor and prevent diseases. The industry includes a wide range of technologies and areas. These are equipment, biochemical products and the creation of software for the analysis and exchange of medical data.

Mesenchymal stem cells are multipotent cells that have the ability to differentiate into cells of bone, cartilage and adipose tissue.

Metagenomics is a branch of molecular genetics that studies genetic material obtained from environmental samples.

Mycorrhiza (fungal root) is a symbiotic association of fungal mycelium with the roots of higher plants.

Microbocenosis is a microbiological set of populations of different types of microorganisms living in a certain biotope.

Mycelium – the vegetative body of fungi and actinomycetes, consisting of thin (1.5–10 μm thick in fungi and 0.5–1.0 μm thick in actinomycetes) branched threads called hyphae.

Social modernization is a set of economic, demographic, psychological and political changes undergone by a traditional society in the process of its transformation into a modern society.

Sedimentary basins are depressions on the crust of any type expressed in the modern structure, filled with undeformed or moderately deformed sedimentary cover and having uniform fluid-dynamic systems.

Paradigm («paradeigma» – Latin example, sample) is a model of rational scientific activity accepted by the scientific community, a set of explicit and implicit (and often unconscious) prerequisites that determine scientific research and are recognized at this stage of the development of science.

Combined-cycle mode is a combination of using gas and steam turbines in one boiler.

Pedagogy of autonomy is teaching methods aimed at increasing independence in students. The main goal is to introduce students to learning strategies and useful tools that will help them effectively educate themselves in the future.

Microdegree pedagogy is a short professional course that teaches specific skills or thematic units, focuses on career development and is designed for people who have previously had no opportunity to study or have low levels of digital literacy.

Predictor – prognostic parameter, forecasting tool.

Proteomics is a branch of molecular biology devoted to the identification and quantitative analysis of proteins.

Sequencing – proteins and nucleic acids (DNA, RNA) – determination of their amino acid or nucleotide sequence.

Secularization (from the Latin saeculum - human age, life span, worldly state) is the process of liberating all spheres of public and personal life from the control of religion; in the broad sense of the word, secularization begins with the distinction between the sacred and the profane, i.e. with the desacralization of some areas of life.

Network-centric warfare is a form of military conflict in which an increase in the combat power of a group of troops (forces) is achieved through the creation of an information and communication network connecting information sources (intelligence), command and control agencies and means of destruction (suppression). It is ensured that participants in operations receive reliable and complete information about the situation in almost real time.

Social entropy is a measure of the deviation of a social system or its individual link from the state accepted as a reference (normal, expected) state, which (deviation) manifests itself in a decrease in the level of organization, operating efficiency, and rate of development of the system. Social entropy is associated with the presence of objective uncertainty in the state of the environment, human activity, management and planning errors, lack of knowledge (information) in the process of organizing (setting up) the system in question - an enterprise, institution, sector of the national economy, society as a whole.

Turboexpander – a turbine that uses the pressure drop in the natural gas network

Urbanization (from Latin urbanus - urban, urbs - city) is a historical process of increasing the role of cities in the development of society, causing changes in the socio-professional and demographic structure of the population, influencing its culture, lifestyle, psychology, etc. The main indicator of urbanization is the increase in the share of the urban population.

A factor (from the Latin «factor» – the creator of something) is a driving force, the cause of any process, determining it or determining its character. In the scientific and technological community, a factor is also called a moment, an essential circumstance in a process or phenomenon.

Foresight research is the identification of promising scientific and technological areas that could form the basis of a long-term scientific and innovation policy for the country's development.

Ectomycorrhiza is the formation of a sheath or mycorrhizal tubes on the roots due to fungal hyphae that entwine the root in a dense network and penetrate through the root rhizoderm, spreading through the intercellular spaces without penetrating into the cells.

CONTENT

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