RESEARCH PAPER

ENVIRONMENTAL CONSEQUENCES OF THE CAPITAL RELOCATION IN THE REPUBLIC OF KAZAKHSTAN

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ABSTRACT. The large-scale socio-economic and political changes that have taken place in the post-Soviet space since the early 1990s have led to cardinal transformations of the economy and settlement in the former Soviet republics. The purpose of the study is to identify patterns and main features of the transformation of the environmental situation in the old and new capitals of the Republic of Kazakhstan. The subject of this article is the ecological transformation in former and modern capitals of the Republic of Kazakhstan, which was affected not only by post-Soviet changes but also by the transfer of capital functions from Almaty to Nur-Sultan.

For a comprehensive analysis of the situation, the state of atmospheric air, water, soil and green spaces were considered. Quantitative calculations and qualitative assessment of the ecological situation showed that the environmental situation of both cities in 2020 was very similar, but the environmental state transformation index does not reach the level of Almaty due to the higher self-cleaning potential of the city and a newer and, accordingly, more environmentally friendly traffic flow. In two cities over the past 20 years, we registered a negative trend in impact level on water sources: a decrease in water consumption in Almaty by 45%, in Nur-Sultan by 27% since 2000. Modernization of plumbing and sewerage systems can reduce water leaks and improve wastewater transport to wastewater treatment plants. In 1998–2020, the environmental situation in Nur-Sultan changed much faster than in Almaty due to the low base effect and the transfer of capital functions because of the emissions from motor transport. However, for Almaty and Nur-Sultan, it can be concluded that the environmental situation by 2020 had been deteriorating much faster than it improved after the collapse of the USSR.

KEYWORDS: air pollution, solid wastes, integrated analysis, environmental conditions, environmental quality, Nur-Sultan, Almaty

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INTRODUCTION

After gaining independence, the Republic of Kazakhstan has seen significant political and socio-economic changes. One of the examples of these transformations is the transfer of the capital from Almaty to Nur-Sultan (former Astana). The transfer of capital changed the economic structure of the cities (Zimmerman 2010), their demographic situation, and, accordingly, this led to dynamic changes in the environmental situation (ES) in the cities.

The most visible environmental impacts are due to innovations and technical progress. Changes in economic and urban planning conditions, population, economy, and transport development changed anthropogenic impact on the urban environment (Tarkhov 2010; Mukhamedzhanov 2011).

The relevance of studying environmental consequences of changes in the ecological situation of capital cities is preconditioned by the fact that the capitals are distinguished by the fastest rate of change in the quality of the urban environment – after the adoption of the capital status, the population in Nur-Sultan increased by 295% from 1997 to 2020; in Almaty, this indicator increased by 64%, which both, directly and indirectly, increases the anthropogenic load. The share of Almaty and Nur-Sultan in the total impact on atmospheric air of Kazakhstan in 1997–2020 was 2.3–4.0%, the total contribution of the two cities to the accumulation of municipal waste in Kazakhstan is 31% (for 2020) (Statistics agency…2021).

To identify and analyze these consequences, it is important to assess changes in the nature and structure of anthropogenic impact on the environmental components (air, water and soil). In addition to analyzing key factors, it is necessary to conduct a comprehensive assessment of the transformation of the environmental situation.

The purpose of the study was to identify and analyze the environmental consequences of the transfer of capital functions using the case of the Republic of Kazakhstan.

Current studies of the topic

Capitals are a specific class of cities (most often significant). They are the centers of life in general, economics, science, and accelerated technological progress (Gottman 1990; Lappo 1997; Hirschhausen 2001).

The transfer of the capital is a unique phenomenon in the history of post-Soviet states caused by specific reasons (Treivish 2009; Rachmawati 2021). Soon after the collapse of the USSR in 1997, Tselinograd received the official status of the capital and was renamed into Astana and then into Nur-Sultan (Akimat website… 2021).

The transfer of the capital was due to the influence of various factors (Aksenov 2006; Kovacs 1999). Because of the negative reasons, the following can be distinguished:

1. Natural and ecological factors

Almaty is located in a seismic hazard zone – in a mountainous area with tectonic faults and sometimes destructive mudflows. Also, the location in the foothill basin negatively affects the environment. Temperature inversion and city relief contribute to the excessive accumulation of pollutants within the city. These factors do not correspond to the environment required to perform the capital's functions. From the environmental point of view, these factors negatively affect the life quality of the city's population. On the other hand, Nur-Sultan is located on a plain, which contributes to the removal of emissions outside the city limits and, in general, improved self-cleaning potential of the atmosphere (Walter 2021).

2. Socio-economic and environmental

According to the former President of the Republic of Kazakhstan, the transfer of the capital was scheduled after gaining independence. First of all, this was due to the geopolitical position of Nur-Sultan (Astana), its crucial strategic location in the center of the Eurasian continent, which makes the new capital a geopolitically important and economically beneficial cultural and national communication, transport hub, and a specific transit bridge between Europe and Asia (Kaufmann 2018).

The population of Almaty is growing rapidly. This is the reason for several environmental problems: air pollution due to increased anthropogenic impact, increased pollution of water resources, soil cover, etc. Another acute problem in Almaty is the lack of territory for constructing residential buildings due to the constantly growing population. The city of Almaty is located in the foothills, limiting the city's expansion in space (Akhmetzhanova and Spanov 2001).

On the other hand, the location of Almaty in the south of Kazakhstan near the Chinese border can be attributed to foreign policy factors – the Almaty region borders on the Xinjiang Uygur Autonomous Region of China with an unabated national Uyghur independence movement (Smirnyagin 2011). Also, until 1998, the problem of joint borders between China and Kazakhstan and the problem of water shortage remained unresolved (Water resources…2021). In the event of a conflict, the southern borders of the republic remain vulnerable (Didko 2001).

The positive reasons mainly relate to the advantages of the new capital, Nur-Sultan. Positive reasons include the following (Rossman 2012):

1. Striving to consummate a regional ethnic-demographic balance, inspirational migration from labor-surplus southern regions to industrially developed northern cities, involving the Kazakh population in industrial and agricultural production in central and northern Kazakhstan. Five regions were disbanded, and the regions with the largest share of the Russian-speaking residents were unified with the regions with the largest share of the Kazakh population. By 2010, the number of residents in the capital exceeded 700 thousand people, most of whom were representatives of the titular nation – ethnic Kazakhs (65%). In 1989, Kazakhs made up only 18% of the city's population.

2. The transfer of the capital to the country's geographic center, along with administrative transformations, also contributed to strengthening the state's territorial integrity, attracting investment, accelerating economic recovery of the region and development of the infrastructure of the new capital (Bhavna 1999; Ghalib 2021).

3. The need for geopolitical use of the middle position of the republic between Europe and Asia and the possibility of overcoming the one-sided distribution of production forces across the state's territory (Raimov 1971; Shatz 1992).

MATERIALS AND METHODS

To assess the ecological situation in cities we used statistical, historical, comparative-descriptive, and linear scaling methods. They allowed calculating the complex ecological transformation index.

Urban environmental studies based on works of specialists, textbooks on geo-urban studies, encyclopedias of Almaty and Nur-Sultan, and capital studies by foreign political scientists and researchers.

The work used national statistical compilations, bulletin archives, Internet resources of the Committee on Statistics, comprehensive reports on the state of air quality in the cities of Nur-Sultan and Almaty, reports on the state of the environment by independent experts, yearbooks of the national meteorological service Kazhydromet; encyclopedic reference books and literary sources.

RESULTS AND DISCUSSION

Selection of priority components for a comprehensive index in the environmental impact of the capital cities transfer

The ecological consequences of the transfer of capital functions are expressed in the transformation of the environmental situation.

The transformation of the ecological situation is a complex and multidirectional process with both positive and negative tendencies. It represents a change in the parameters and consequences of the impact (factors), both anthropogenic and natural.

To study changes in the ecological situation, several groups of indicators can be distinguished. They are presented in Table 1. To calculate the complex index, the absolute and relative indicators of anthropogenic impact on the atmosphere, water sources, and the city's population, both a source of a negative impact and its recipient, were selected.

Absolute scores show the magnitude of the impact (Lawrence and Roderick 1997), while relative scores reflect the difference in effects relative to the population or city area.

The anthropogenic impact on the environment is described not only by the indicators presented in the table. In each block, it is impossible to analyze some important sources of pollution due to the lack of information data. This is because the regional statistical bulletins of Kazakhstan do not consider indicators such as emissions from mobile sources, water intake volumes, and amount of wastewater received without treatment. Also, we are lacking data on other types of pollution (noise, radiation, biological).

Methodology for calculating the complex index of the ecological situation transformation

To study the environmental consequences of the transfer of the capital from Almaty to Nur-Sultan using a complex index, it is

Table 1. Indicators of the ecological situation transformation

Index	Peculiarities	Index unit
A. Impact and air quality		
A1. Emission from stationary sources	All businesses in the city to varying degrees affect the atmospheric air, the most significant contribution of emissions from stationary sources is made by combined heat and power energy enterprises. Emissions are an absolute indicator that reflects the extent of pollution.	emission volumes (thousand tons/year)
A2. Air quality index (AQI)	AQI is a complex indicator that reflects how many times the total air pollution by five substances exceeds the permissible value.	The Air Quality Index is the sum of exceeding the permissible concentrations by the average annual concentrations based on measurement of particulate matter ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) emissions
A3. Level of motorization	With the development of road transport, the negative impact on the atmosphere increases. Emissions from mobile sources are «low», poorly dispersed due to building density combined with a small area of green space (Slashchev and Iskakov 2012). The use of the motorization growth indicator for comparing Nur-Sultan and Almaty is quite correct, since the area of the cities and the density of the street and road network are similar, and the indicator deals with an equal network density since vehicle emissions depend not only on traffic intensity, but also on the kind of transport (Abilov at al. 2021). The number of cars is a proxy indicator, it would be more correct to take into account vehicle emissions, but such data are not available for a significant part of the study period.	number of cars / 1000 inhabitants
B. Impact on water sources		
B1. Water consumption	The volume of water consumption is a relative indicator. It reflects the impact on water sources and characterizes the population's water supply (Sources of water supply… 2021). The total volume of all water consumption was taken into account.	thousand cubic meters / per 1 inhabitant
B2. Wastewater volume	Uncontrolled wastewater discharge reduces the self-cleaning capacity of water ecosystems and leads to the ecological disadvantages of the primary water sources of the cities. Wastewater volume is an absolute indicator.	thousand cubic meters / per 1 inhabitant
C. Waste management		
C1. Volumes of accumulation of toxic waste (TW) from industrial enterprises.	Annual volumes of incoming maintenance exceed the permissible accumulation rates. Large volumes of accumulated toxic waste from industrial plants require high storage safety. Incorrect disposal of TW can cause a severe impact on the environment, and if it enters the atmosphere in larger volumes, it can cause an environmental disaster.	tons
C2. Municipal solid waste (MSW) accumulation volumes	The increase in the volume of MSW leads to the problem of overloaded landfills and, accordingly, increases the number of unauthorized landfills. Spontaneous dumps harm the soil and cause organoleptic discomfort for residents living near the landfill.	tons
D. Population		
D1. Population	The population is an absolute indicator that reflects the scale of anthropogenic impact. This indicator indirectly or directly affects the level of water consumption, the formation of MSW, and the level of motorization.	thousand people
E. Green zones		
E1. Area of green space within the city limits	Changing the area of green spaces affects not only the ecological situation but also the comfort of living in the city.	% of green areas in the total area of the city

important to determine the time interval, with a corresponding single set of indicators that will help characterize the changes. The capital status was transferred in 1997; therefore, to reflect the change in the ecological situation in two cities, the period from 1988 to 2020 was chosen.

This period can be divided into three nominal periods:

1. Pre- transfer period – from 1988 to 1998,
2. Post-transfer period – from 1998 to 2008,
3. Current period – from 2008 to 2020.

The National Statistical Committee has mainly produced regional statistics since 2000. The website of the hydrometeorological service of the Republic of Kazakhstan provides an archive only since 2015. All the calculations are based on data (Environment in the countries… 2001–2020; Environmental protection….1989; National Air Quality…1997; Nur-Sultan industry website…2021; Statistics agency…2021; Ten years of the Commonwealth…. 2021).

Based on the available data of articles and studies in the field of city ecology and official statistics, which contains only some indicators of atmospheric air pollution, we built a comparative table with the following indicators:

Because the developed system of indicators for assessing changes in the ecological situation includes many indicators with different dimensions (Bityukova and Borovikov 2018), the data are normalized using the linear scaling formula (1):

$$A_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

where *i* is an indicator;

X_i –the value of the indicator for the yth year;

X_{max} and X_{min} – maximum and minimum values of indicators in two cities; Ai – normalized indicator (indicator index).

The linear scaling method helps to display the values of each indicator in the range from *0* (at $X_i = X_{min}$) to 1 (at $X_i = X_{max}$), keeping all the proportions between the individual values.

Calculating the complex index of changes in an environmental situation when transferring capital functions from 1988 to 2020.

To normalize indicators of different dimensions, we applied a linear scaling formula. Each indicator was calculated for the period from 1988 to 2020. The results of data calculations are presented in Table 3.

In order to take into account all groups of indicators, the scores for each group are summed up. Differences are more accurately taken into account for individual indicators when summing up the dynamics of natural growth (decrease) in the complex index of changes in the ES, and each indicator is monitored within the boundaries of stable (reference) points (fig.1).

Table 2. Comparative characteristics of Almaty and Nur-Sultan by several indicators directly or indirectly affecting the ecological situation

Index	Year	Almaty	Nur-Sultan
Emissions from stationary sources (thousand tons)	1998	16.2	41.5
	2020	43.0	56.4
AQI	1998	9.8	1.3
	2020	7	7
Traffic flow (cars / 1,000 inhabitants)	1998	188	134
	2020	242	234
Population, thousand people	1998	1117	300.5
	2020	1802	1032
The area of green spaces within the city limits, ha	1998	4.414	2.903
	2020	2.612	4.186
City area located in an unfavorable ecological zone (%)	1998	50	10
	2020	80	50

Table 3. Normalization of indicators from 1988 to 2020 for Almaty and Nur-Sultan according to the linear scaling formula

		Index	Year	Almaty	Nur-Sultan
A	A1	Emissions from stationary sources	1988	0.44	1.00
			1998	0.03	0.37
			2008	0.00	0.40
			2020	0.40	0.60
	A2	AQI	1988	0.68	0.00
			1998	0.75	0.03
			2008	1.00	0.61
			2020	0.51	0.52

A	A3	Traffic flow	1988	0.62	0.00
			1998	0.44	0.20
			2008	1.00	0.65
			2020	0.67	0.64
B	B1	Water consumption	1988	0.32	0.00
			1998	0.54	0.34
			2008	0.81	0.78
			2020	1.00	0.94
	B2	Wastewater volume	1988	0.39	0.00
			1998	0.62	0.49
			2008	1.00	0.73
			2020	0.87	0.84
C	C1	Volumes of accumulation of toxic waste (TW) from industrial enterprises.	1988	0.89	0.00
			1998	1.00	0.19
			2008	0.48	0.24
			2020	0.51	0.32
	C2	Municipal solid waste (MSW) accumulation volumes	1988	0.54	0.28
			1998	0.65	0.49
			2008	0.76	0.71
			2020	1.00	0.94
D	D1	Population	1988	0.50	0.00
			1998	0.55	0.03
			2008	0.23	0.23
			2020	1.00	0.50
E	E1	The area of green spaces within the city limits	1988	0.43	0.61
			1998	0.49	0.92
			2008	0.00	0.61
			2020	1.00	0.55

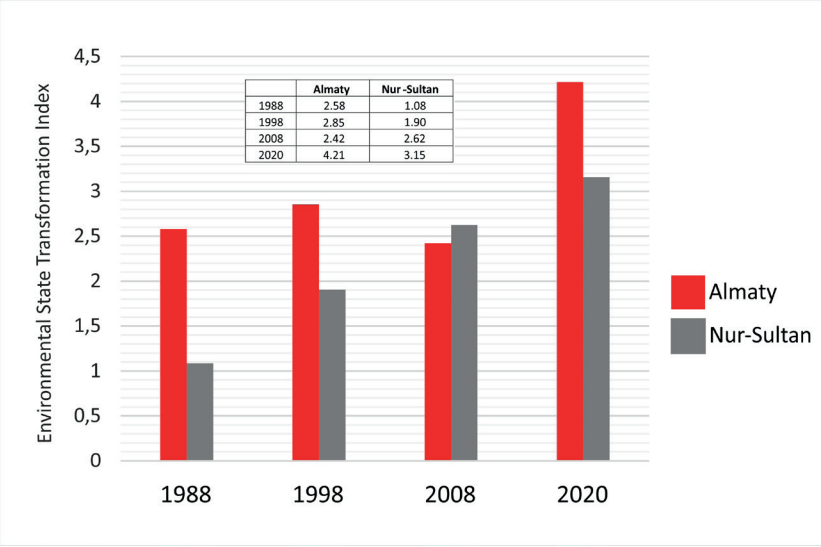

Fig. 1. Environmental State Transformation Index for three time periods: from 1988 to 1998, from 1998 to 2008, and from 2008 to 2020

This graph reveals some similarities and differences in the change in the ES of Almaty and Nur-Sultan:

1. In the period from 1988 to 1998, after the collapse of the USSR, the impact in two cities was decreasing. This is due to the restructuring of the economy and the closure of some industrial enterprises (Almaty cotton mill, Almaty house-building plant). In the first years of independence, in connection with the transition to a market economy and market relations, all sectors of the national economy were in crisis. As a result, in 1991-1996, production was significantly reduced. The reduction in production volume was: in the chemical and petrochemical industry - 71%, in light industry - 84%, in the woodworking industry - 76%, in mechanical engineering and metalworking - 64%, in construction - 82%, in electricity generation - 30%, ferrous metallurgy - 30%, non-ferrous metallurgy -28%, fuel production -40%. It was necessary to solve the following tasks: restructuring the economy, its reorientation to modern science-intensive technological industries; creating a socially oriented market (Toksambaeva and Bazarbaeva 2017). The transformation index in the former capital is 2.2 times higher than in Nur-Sultan.

During the Soviet period, Almaty was one of the largest industrial centers of Kazakhstan. A high employment rate increased the population and, accordingly, the level of motorization (Koldobskaya 2014).

The implications of the transfer of metropolitan functions are highlighted in the graph for the period from 1998 to 2008. The new capital is characterized by a sharp threefold deterioration in the ES; the reason for this is an increase in the impact on all four indicators, in particular, on AQI, which changed from 0.03 to 0.61.

The growth of the indicator in both cities is due to the development of the economy of Kazakhstan, an increase in investment flows, and, accordingly, an increase in the population. The ES has moderately deteriorated over the past 12 years (from 2008 to 2020) in both cities. The values of the transformation index in Alma-Ata and Nur-Sultan are associated with the deteriorating environmental situation in all respects. In Almaty, the largest contribution to the deterioration is made by an increase in the population, and in Nur-Sultan, due to the rise in the level of motorization and the volume of emissions from stationary sources of pollution.

Calculation of the complex transformation index of the ES from 2000 to 2020

Table 4 analyzes in more detail the environmental consequences of the transfer of the capital city presenting the complex index.

Official statistics on the impact on water sources and waste management have been taken into account only since 2000. Therefore, the study takes time intervals from 2000 to 2008 and 2008 to 2020.

After summing up the indicators by cities, we calculated the complex indices presented them in Figure 2:

Table 4. Normalization of indicators according to the linear scaling formula for Almaty and Nur-Sultan from 2000 to 2020

		Index	Year	Almaty	Nur-Sultan
A	A1	Emissions from stationary sources	2000	0.00	0.77
			2008	0.02	0.71
			2020	0.69	1.00
	A2	AQI	2000	0.75	0.00
			2008	1.00	0.58
			2020	0.49	0.48
	A3	Traffic flow	2000	0.28	0.00
			2008	1.00	0.61
			2020	0.65	0.61
B	B1	Water consumption	2000	1.00	0.26
			2008	0.94	0.09
			2020	0.23	0.00
	B2	Wastewater volume	2000	1.00	0.00
			2008	0.86	0.08
			2020	0.87	0.38
	B3	Total area equipped with a sewerage system	2000	1.00	0.94
			2008	0.88	0.39
			2020	0.10	0.00
C	C1	Accumulation of TW	2000	0.02	1.00
			2020	0.05	0.98
	C2	MSW accumulation	2008	1.00	0.00
			2020	0.99	0.79

D	D1	Population	2000	0.53	0.00
			2008	0.66	0.16
			2020	1.00	0.46
E	E1	Area of green space within the city limits	2000	0.45	0.85
			2008	0.28	0.78
			2020	1.00	1.25

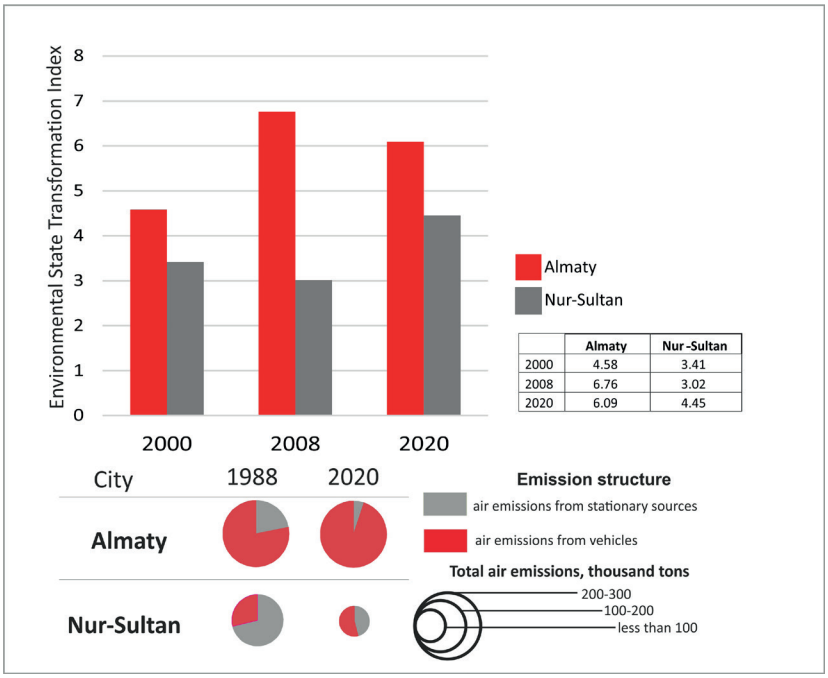

Fig. 2. Environmental State Transformation Index for three periods: from 1988 to 1998, from 1998 to 2008, and from 2008 to 2020

This graph shows the differences in the transformation of the ES:

1. In the period from 2000 to 2008 – the first decade after the transfer of capital functions there was a stabilization of the impact level, which is typical for the new capital (RK news portal, 2021). This is due to a decrease in the impact in Block B – indicators of effects on water sources and C – waste management. An increase in the area of the city equipped with a sewer network resulted in a wastewater decrease. For block C we note a decrease in MSW. The annual increase in the volume of municipal waste in the city exceeds the acceptable standards by an average of 125 kg/person per year; many spontaneous dumps are emerging (about 160 in 2020). However, we registered an increase in a set of atmosphere impact indicators. The transfer of the capital to Nur-Sultan accelerated the development of the infrastructure on the left bank with a new administrative center of the capital. This prompted the construction industry and transport infrastructure (New interchanges of Almaty 2021); respectively, the number of motor vehicles increased.

For the city of Almaty, the ES is deteriorating; this is due to an increase in indicators for each of the blocks, in particular, the population is growing, and the impact on the atmosphere is increasing, including the level of motorization and AQI.

2. From 2008 to 2020, the ES transformation index in two cities is changing.

For the city of Nur-Sultan, we registered an increased impact on the atmosphere and the growing pollutant emissions. A feature of Nur-Sultan and Almaty is the preservation and sometimes the development of low-rise buildings. Moreover, Almaty is largely gas-fueled, whereas Nur-Sultan is coal-fueled. Moreover, in Nur-Sultan, there are quarters of old buildings left from Tselinograd, summer cottages, which are quickly demolished, there are new cottage quarters, which are also demolished. In Nur-Sultan these quarters undergo significant transformations, whereas in Almaty, they are quite stable. In 2017 population reached 1 million inhabitants, and the volume of MSW generation increased accordingly. In terms of the number of cars per person, the new capital has caught up with Almaty. At the same time, the impact on water sources decreases, which is associated with a reduction in water consumption due to the introduction of water metering devices, and the area of the territory, which is equipped with a sewer network, also increases.

For Almaty, we registered a slight decrease in the composite index by 0.4. This is also mainly due to a reduction of the impact on water sources: the level of water consumption is decreasing, the area equipped with a sewerage system is increasing. The population has increased significantly (by 36% compared to 2008). The level of MSW accumulation increased accordingly. At the same time, the population's motorization level has changed insignificantly, and the AQI has decreased.

CONCLUSIONS

The ecological consequences of the transfer of the capital city are qualitative and quantitative changes in the factors, components, and interaction of anthropogenic influence and the self-cleaning potential of the environment. Together with the physical and geographical

factors of the formation of the ES in Almaty and Nur-Sultan, these consequences have a multidirectional nature and their characteristics. With the acquisition of the independence of Kazakhstan, the capital status was transferred to the city of Nur-Sultan. Urbanization of the new capital is accelerating. The redirection of migration flows has sharply increased the population of Nur-Sultan and slowed down the rate of population growth in the old capital from 1999 to 2001. During this period, the migration growth of the population of Almaty is 35% lower than the city of Nur-Sultan.

On the analysis of the complex index of the ecological situation transformation and the peculiarities of the development of the two capitals of Kazakhstan from 1988 to 2020 allowed for the following conclusions:

1. The Almaty city has many inherited factors of influence: the city's population already in 1998 was more than 1 million, the presence of industrial enterprises left after the collapse of the USSR. Almaty, due to the lack of opportunities for spatial expansion due to the city's location in the foothill basin and an increase in the population and traffic flow, has seen a moderate deterioration in the environmental situation.

2. Nur-Sultan underwent a sharp change in the environmental situation due to an increase in the population and the level of motorization.

The ecological situation of the two cities in 2020 is almost equivalent, but the ES transformation index does not reach the level of Almaty due to the higher self-cleaning potential of the city and a newer and, accordingly, more environmentally friendly traffic fleet.

3. Over the past 20 years the two cities registered a positive trend in the impact on water sources: in Almaty water consumption decreased by 45% and in Nur-Sultan it decreased by 27%. Modernization of plumbing and sewerage systems can reduce water leaks and improve wastewater transport to wastewater treatment plants.

4. From 1998 to 2020 the environmental situation in Nur-Sultan changed much faster than in Almaty due to the low base effect and the transfer of capital functions if emissions from motor transport are not resolved. The transformation index of the former capital is 2.2 times higher than in Nur-Sultan.

5. Nur-Sultan will increase its impact on the Akmola region due to the development of the agglomeration, pollution from motor transport will increase every year, but t the environmental situation will not reach the level of Almaty due to the higher self-cleaning potential of the city and a newer and, accordingly, more environmentally friendly transport infrastructure. In addition, Almaty is an established million-plus city, and its planning structure was formed in previous years with a view to a significantly lower level of motorization, while Nur-Sultan is an actively developing and expanding city with modern and future needs.

However, for both cities, it can be concluded that by 2020 the environmental situation has been deteriorating much faster than it improved after the collapse of the USSR.

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