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Forecast of the Use of Natural Waters of Kazakhstan under Anthropogenic and Climate-Driven Changes.

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ABSTRACT

Consumption of water and land resources grows from year to year, thereby increasing anthropogenic impact on the subsoil, soil, NW systems and geodynamics of the geological structures. The improved criteria for assessing the state of the environment and foundation of the socio-ecological-economic efficiency of water use are suggested. A National Strategy of water supply and consecution of solving problems of water management in Kazakhstan are developed. However, these problems need to be processed in relation to climate change.
Keywords. Analysis of adaptive water management measures, natural waters, water supply, natural resource potential.

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INTRODUCTION

The climate of the Republic of Kazakhstan is sharply continental, as its territory is far from the oceans and seas. The difference in the dates of snow cover occurrence in Kazakhstan is about 2-3 months. On plain territory, the average air temperature in January from north to south rises from minus 17 °C to minus 1 °C, in July – from plus 20 °C in the north to +30 °C in the south. The average annual temperature in the north is about 1 °C, in the extreme south – plus 13 °C [1, 2].

Sovereign and independent development of the country is provided if the economy of Kazakhstan is successfully integrating into the global economy and, accordingly, takes its rightful place in the global economic system. There are all necessary conditions, and legal base for social and economic development of the country is created for this purpose [3, 4]. Proceeding from the requirements [5] and given that the Republic of Kazakhstan should achieve the effectiveness of the use of resources (EUR) index not less than 43% in 2013-2018 to enter the top fifty most competitive countries in the world, it is necessary to increase the effectiveness of the use of resources, increase the life expectancy of the population and ensure the improvement of the environmental sustainability index. At present, the development of the economic power of the state should not be limited by the critical conditions in the environment. Both the requirements of international regulations and the developments of environmental protection in the Republic of Kazakhstan are developed in this direction [6, 7, 8, 9].

According to [5], the population of the republic can be expected to be 17.13 mln people in 2018 and 18.18 mln people in 2024. In 2010, Kazakhstan's GDP totaled to 21,815 bln tenge. GDP growth in comparison with 2009 was 7.3%. Agricultural land used by land users in 2012 totaled to 89,802.2 thous ha, of which arable land was 23,583.9 ha, hayfields and pastures – 63,074.6 thous ha. The volume of gross agricultural output in 2012 in the whole republic totaled to 1,442.6 bln tenge, of which crop production was 662.6 bln tenge. In 2012 (compared to 2009), the growth of cattle was achieved n all categories of farms by 1.0% (2012 – 6,175.3 thous heads), sheep and goats – by 1.0% (2010 –17,988.1 thous heads), horses – by 1.1% (2012 – 1,528.3 thous heads), camels – by 1.1% (2012 – 169.6 thous heads), and poultry – by 1.0% (2012 – 32.8 mln heads), the number of pigs – by 1.0% (2012 – 1,344.0 thous heads).

Modern industrial and agricultural economy of the Republic of Kazakhstan has been formulated in the second half of the last century. Today, the specialization of Kazakh export is raw materials [10, 11, 12, etc.]. Therefore, the economic dependence of the Republic on external factors remains at a high level, and particularly on the instability of the global situation on the commodity markets. Due to the fact that the development of many types of raw materials becomes more expensive, commodity exports in the future may not be profitable.

Kazakhstan takes one of the leading places in the world in terms of diversity and quantity of mineral resources. The republic holds a strong position in the global market for copper, chromium, uranium, lead and zinc, and has a significant impact on the regional market of iron, manganese, coal and aluminum (Table 1).

Table 1: Production of energy resources in the Republic of Kazakhstan, mln tons [13, 14]

Name of resources	2005	2006	2007	2008	2009	2010	2011	2012
Coal	84.9	86.9	86.6	96.2	94.4	111.1	100.8	110.9
Crude oil	45.4	50.7	50.9	54.3	55.6	58.6	64.4	68.1
Natural (rock) gas, mln m^3	16.6	22.1	24.9	26.4	29.2	32.9	35.9	37.4
Iron ore	19.3	20.3	19.5	22.3	22.6	21.5	46. 2	50.2
Copper ore	34.9	30.4	34.1	34.1	31.1	32.6	30.6	32.0
Production of:								
Electricity, bln kWh	63.9	66.9	67.9	71.7	76.1	80.3	78. 7	82.6
Natural water, bln m^3	2.2	2.4	2.4	2.5	2.7	2.8	2.6	2.8

It is clear from Table 1 that mining operations increase from year to year, which means that the growing volume of mining operations inevitably leads to an increase in man-made pressures on the subsoil, soil, NW systems and geodynamics of the geological structures. Only in the 2012, the emissions in the country amounted to 2,226.5 thous tons.

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In 2012 (compared to 2005), emissions decreased by 22.8% in whole, gas and liquid substances – by 26.3%. Especially large amounts of industrial waste emissions – sulfur dioxide – decreased by 47.8%, while carbon monoxide and nitrous oxide increased respectively by 1.9% and 11.2%.

The Republic of Kazakhstan has vast land resources. The territory of Kazakhstan is 272.49 mln ha, of which more than 222.5 mln ha or 81.6% is agricultural land. Over 2006-2012, the area of arable land increased slightly from 21,968.1 thous ha to 23,583.9 thous ha (Table 2). Lands of agricultural enterprises, peasant (farming) lands and lands in personal use of citizens increased slightly over the above period.

Table 2: Agricultural land used by land users as of November 1, thous ha [13,14]

Year	total agricultural land used by land users	of which				
		lands of agricultural enterprises	peasant (farming) lands	lands in personal use of citizens	of which	
					private farms	collective and individual gardens and orchards
All agricultural lands						
2006	77,972.4	43,419.5	34,227.7	325.2	179.9	145.3
2007	78,383.0	41,439.2	36,634.9	308.9	174.2	134.7
2008	81,261.8	41,908.4	39,064.1	289.3	164.3	125.0
2009	83,406.3	42,091.2	40,992.6	322.5	200.8	121.7
2010	85,470.4	42,310.6	42,840.8	319.0	197.3	121.7
2011	88,165.3	42,700.1	45,140.4	324.8	201.8	123.0
2012	89,802.2	42,815.1	46,685.7	301.4	174.7	126.7
Arable land						
2006	21,968.1,	12,921.4,	8,815.6,	231.1	128.5	102.6
2007	22,152.0,	13,371.5,	8,560.2,	220.3	123.0	97.3
2008	22,106.1,	13,583.1,	8,312.2,	210.8	120.8	90.0
2009	22,117.6,	13,678.3,	8,227.3,	212.0	125.3	86.7
2010	22,704.7,	14,043.9,	8,448.3,	212.5	125.2	87.3
2011	23,407.8	14,399.1	8,791.9	216.8	128.1	88.7
2012	23,583.9	14,504.0	8,861.8	218.1	128.0	90.1
Hayfields and pastures						
2006	53,142.7,	29,133.0,	23,976.6,	33.1	29.2	3.9
2007	53,324.4,	26,869.4,	26,421.1,	33.9	30.1	3.8
2008	55,824.3,	26,960.1,	28,837.4,	26.8	23.1	3.7
2009	57,701.3,	26,928.0,	30,713.4,	59.9	56.2	3.7
2010	59,386.5,	26,905.0,	32,425.1,	56.4	52.6	3.8
2011	61,644.1	26,984.0	34,601.9	58.2	54.3	3.9
2012	63,074.6	26,959.1	36,083.2	32.3	27.2	5.1

Water resources of the Republic of Kazakhstan are 100.5 km^3 and are very unevenly distributed across the territory. Water supply of certain areas and states is estimated through the annual volume of surface water runoff, forecasting and proven reserves of groundwater per unit of the area or per capita. Indicators of availability of surface water resources for Kazakhstan in an average dryness year are the lowest among the CIS countries (Table 3).

Table 3: Indicators of availability of surface water resources for Kazakhstan and neighboring states, thous m^3/year [15]

Indicators	States			
	Kazakhstan	Uzbekistan	Kyrgyzstan	Russia
Water supply				
1 km^2 of area	37.6	233	248	248
1 inhabitant	6.66	7.87	13.9	30.8

Comparison of water supply by water economic districts shows that there are more affluent regions (Yertys river basin); there are regions where water is deficient, for example, Zhaiyk-Caspian and Nura-Sarysu basins by surface water (Table 4).

Table 4: Availability of surface water resources for river basins, thous m^3/year [15]

Basin inspections	Total resources		Formed on the own territory	
	per 1 km^2	per 1 inhabitant	per 1 km^2	per 1 inhabitant
Aral-Syrdarya	66.07	6.94	15.80	1.66
Balkhash-Alakol	65.91	8.07	36.26	4.44
Esilsky	10.58	1.32	10.58	1.32
Zhaiyk-Caspian	20.02	6.05	6.44	1.95
Irtysh	100.60	16.77	77.37	12.90
Nura-Sarysu	4.55	1.15	4.55	1.15
Tobol-Torgai	5.39	1.95	5.39	1.95
Shu-Talas	26.35	3.94	10.24	1.53
Average across RK	***37.61***	***6.66***	***20.79***	***3.68***

The least water supplied district is Esilsky by surface and groundwater. Dynamics of water intake from water sources for 2006-2012 shows that the volume of water intake decreased from 26,436 in 2006 to 21,538 mln m^3 in 2012.

Total water consumption (water use) over the analyzed period varied slightly from 20,204 in 2004 to 20,856 mln m^3 in 2012. Water consumption for industrial needs and drinking water respectively increased by 28.3% and 20.9% and totaled to 5,632 and 751 mln m^3 of water per year in 2012. The amounts of recycled and re-used water in a water sector decreased from 8,532 in 2004 to 7,899 mln m^3 of water in 2012, which, respectively, totals to 66% and 60% as a percentage of the total water consumption for industrial needs. In contrast, over the same period, volumes of sewage and other discharges into surface water bodies increased by 42.3% (in 2012 – 6,017 mln m^3), the volume of regulatory treated wastewater increased by 36.7% (in 2012 – 257 mln m^3), the volume of untreated and inadequately treated sewage increased 9.6 times (in 2012 - 923 mln m^3).

However, the use of fresh water in the Republic of Kazakhstan over 2005-2012 gradually increased (36.8%) and totaled to 20,856 mln m^3 in 2012 (Table 5). In this case, the need for water irrigation, watering and agricultural water supply increased by 1.1%, and the demand for water for industrial needs increased by 41.4%, while the demand for water for household and drinking needs increased by 25.0%. Both quite logically fit into the problem of the sustainable development of industries and the conservation of natural complexes.

Table 5: Use of fresh water in RK, mln m^3 [13,14]

Name	2005	2006	2007	2008	2009	2010	2011	2012
Total	15242	20204	21422	18442	19906	18 034	19 259	20 856
Of which:								
a) irrigation, watering and agricultural water supply;	10573	12021	11329	10897	11512	10 002	10 932	11 703
b) industrial needs;	3983	4442	4062	4419	5019	5 199	5 104	5 632
c) household and drinking needs	601	621	694	698	709	735	742	751

All this suggests that the importance of sustainable water supply for population and industrial needs remains one of the unresolved problems today, since water resources in the republic are limited and there is a high degree of their contamination.

METHODS

Methodological prerequisites for the rational use and protection of natural resources. The long-term objective is to ensure the socio-economic development of the state and at the same time preservation of the possibility of reproduction and the quality of water at the level of regulatory requirements for water quality –

"sustainable water use". The block diagram of the factors and their interrelationship in solving the tasks of managing the rational use and protection of natural complexes is presented in Figure 1.

When solving problems in the field of sustainable use of natural resources, the priority approaches are the ones in which problems are solved jointly, i.e. problems of economy are not detached from the problems of ecology. This should be based on the condition that the society prefers the environmental issues [3, 16]. So far, the concept of water development has included studies based on the full use of internal resources and a partial mobilization of resources from Yertys, Volga and Zhaiyk. Then the irrigated area in Kazakhstan would be 7.7 mln ha, including 5.3 mln ha of regular and 2.4 mln ha of estuary irrigation [Institute named after S.Ya. Zhuk], and 5.5 mln ha of regular irrigation [Sredazgiprovodkhlopok and Kazgiprovodkhoz]. However, now 1.3 mln ha of land is irrigated, the requirements of natural complexes are not satisfied in full. At the time, the task was to reduce the level of pollution in the environment by 52% by 2012, and to completely eliminate pollution by 2015. However, these requirements are not feasible within a specified time. Nevertheless, it is necessary to reconsider the prospects of development of economic sectors in the regions, substantiate the optimum levels of water resources in river basins and establish possible volumes of runoff rendition from Siberian rivers and the limits of water-saving measures.

These tasks, in accordance with the requirements of the Water Code of the RK [16], are presented as a National Strategy for water supply of the country (Figure 2). Principles for assessment of water resources and water use, as well as the procedure of solving the problem of water supply of the country are shown in Figure 3.

In general, the methodology of substantiation of social, ecological and economic efficiency of environmental and water protection measures is carried out in two stages. At the first stage, the most common criterion is chosen based on the analysis of criteria for assessing the level of pollution of air, water resources and soil. The level of pollution is assessed and environmental damage is determined. The assessment of the state of environmental pollution is set by the integral criteria:

$$IEP = (IWD + IWP) + IAP + (0.2\text{-}0.5)\ ISC, \qquad (1)$$

where IWD is the index of water depletion; the rate of irreversible withdrawal of surface runoff constituting 10-20% of the average annual value of the natural runoff;

IAP is the index of air pollution;

ISC is the index of soil contamination. Even if it is not contaminated now but was once contaminated, then the residual principle works, and soil contamination is partly transferred to the products of the ecosphere.

$$SSER_i = I_i - D_i - C_i + EEA, \qquad (2)$$

where $SSER_i$ is national economic income at the i-th version of flow regulation (at the i-th version of integrated management of water resources in the river basin);

I_i is income of the sectors of the economy at the i-th version of flow regulation (at the i-th version of integrated management of water resources in the river basin, taking into account the positive spillover effects);
D_i is damage caused by the depletion and pollution of water sources at the i-th version of flow regulatio
n (at the i-th version of integrated management of water resources in the river basin, taking into account the negative spillover effects);
C_i is costs of construction of water protection and water management facilities;

EEA is additional economic effect arising from the increasing value of natural resources.

Technical and economic calculations to substantiate the socio-ecological-economic efficiency of water protection and water saving measures are made. The substantiation of the socio-ecological-economic efficiency of use of natural resources while taking into account the interests of the preservation of ecological safety in the environment will base at a new and improved criterion: the dependence (2).

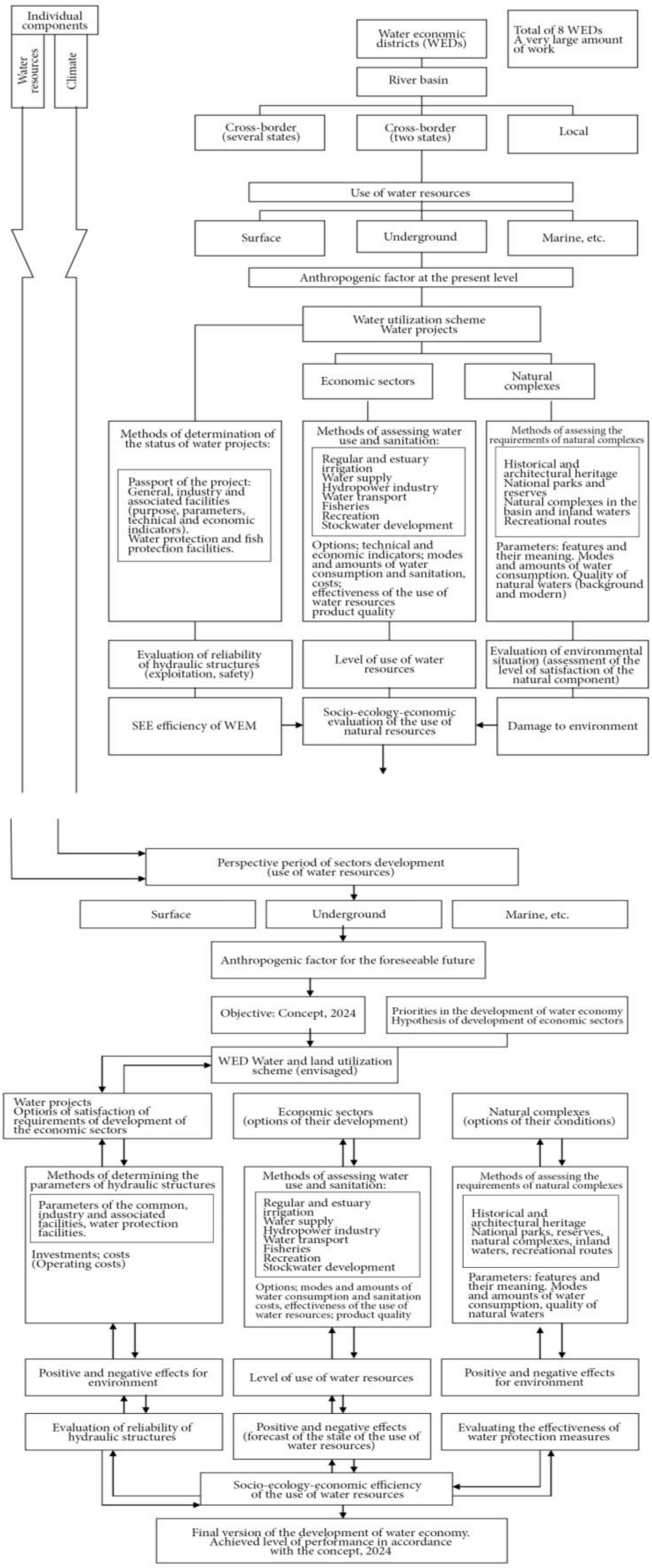

Fig. 1. Forecast of the use of natural waters of Kazakhstan under anthropogenic and climate-driven changes

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Purpose: Ecological safe and economically optimal level of water use and protection of water fund

The main principles of water legislation:
- Prime providing population with drinking water;
- Complex and rational water use with development of modern technologies;
- Use of water objects in a complex with their protection
- Availability at a price of special water use;
- Compensation of the damage caused by violation of the water legislation;

The requirements providing rational use, protection and improvement of condition of waters:
- nature protection requirements when using water objects and water management constructions;
- reduction of dumping of polluting substances in water objects;

Problems of state planning in the field of use and protection of water fund:
- scientific and reasonable distribution of waters between water users taking into account prime satisfaction drinking and domestic needs of the population;
- protection of waters and prevention of their harmful effects.

For this purpose: water management balances, schemes of complex use and protection of waters: the forecast of use and protection of water resources as a part of schemes of development and placement of productive forces and economy branches

Fig. 2. National Strategy for water supply in Kazakhstan

Modern level	
- norms of water consumption and assignment (tendencies) level of satisfaction of requirements of economy branches and natural complexes	- social-ecological-economic efficiency of water resources use.

Perspective level
-priority water consumers (MDC, IWU, AWS, R, FC) and respectively on VHR (FI: Zhayik-Caspian Sea; Esil, Ertis, Nur-transit release, etc.) - hydropower (counter regulator); FI pk - limits of water consumption of other branches of economy

Water management actions in melioration		
- Efficiency of irrigation(OS) - improvement ekological-meliorative conditions of OS - water capacious S.H.K. translation on not water capacious	- drop irrigation (injection watering) - reduction of expenses of water by production unit - revision of irrigation specialization (fruits, wine growing and etc) in FI, etc. economy branches	- the intensive - technologies of an irrigation (the closed soil) - cleaning and use collector drainage of waters

Water management objects	
- Complex of water Systems in VHR - level of equipment of water management objects (monitoring network)	- means of the account and automation of distribution of water; water disposals - water resources management level (α, ß)

Stability of natural complexes	
- assessment of stability of natural complexes at modern level - forecasting of a condition of natural complexes on perspective the nature and their compliance to requirements of the concept of ecological safety	- the principles of justification of ecological stability in a river basin

social-ecological-economic efficiency	
- Development of water sector of economy on prospect of water resources - water management objects on satisfaction of development of a water management - methodology of definition of a positive and negative consequence on a state of environment	- methodology of calculation of SEE of damage from exhaustion and pollution - payment for air as for a natural resource and for special water use - social-ecological-economic efficiency of use of water - optimum level of use of water resources in a river basin

Recommendations about use and protection of water resources in a river basin		
- on environmentally clear products - development parameters irrigated on different levels of water resources of a river basin	- finishing to a standard level of quality of water - ensuring ecological stability	- parameters of development of a water management - recommendations about transformation of the scheme of use

Fig. 3. Consecution of solving problems of water management in the Republic of Kazakhstan

At the second stage, the criterion of socio-ecological-economic efficiency is chosen.

RESULTS

Main priorities of economic development. During all periods of their existence, people fed off the land, and despite occasional crises, the situation has always been stable. The development of the social system and sciences improved the living conditions for everyone, which became the condition for survival and preserving life equilibrium. With the emergence of the commodity exchange, the market itself emerged. At the early stages, the exchange was natural, then after the appearance of money, which has been assigned the status of the means of exchange, the situation remained stable, i.e. in equilibrium. However, the market always requires expanding the scope of sales, which is a resource for the economy. The market requires intensive work of all components of the economy to increase profits. Broad opportunities of trade between countries, between east and west, between north and south are developing.

The basic document [7] stressed that environmental issues should not be considered in isolation from the use of nature resources. For example, the gross domestic product in the Republic of Kazakhstan in US dollars per capita in 1995 totaled to 1,052.1, followed by its steady growth, and in 2012 it totaled to 9,070.0 in US dollars. Life expectancy of the population in Kazakhstan in 1991 was 67.6 years, the lowest value of 63.5 years was observed in 1995, then it slowly grew and reached 68.4 years in 2012. At the same time, morbidity generally increases. For example, the number of registered diseases with the diagnosis set for the first time in 1990 was 50,351.8 per 100 thous people and reached 58,077.2 cases in 2012. However, the greatest value was observed in 2011 – 60,110.05). In Kazakhstan, the number of hospital beds per 10 thous people is 72.4, whereas in Canada and Australia it is only 40. Similar indicators for relatively environmentally safe Kyrgyz Republic suggest that while the human development index declined from 0.908 in 1990 to 0.676 in 1995, gradually rising to 0.719 in 2000 (with a decrease in the gross national product from USD 1,160 in 1991 to USD 300 in 1999 and currently about USD 800), life expectancy in Kyrgyzstan in those periods remained substantially at the same level, about 68.5 years. Hence there is the conclusion that life expectancy and morbidity depend more on the environment than on the income of the population. All these examples are well illustrated in Figure 4.

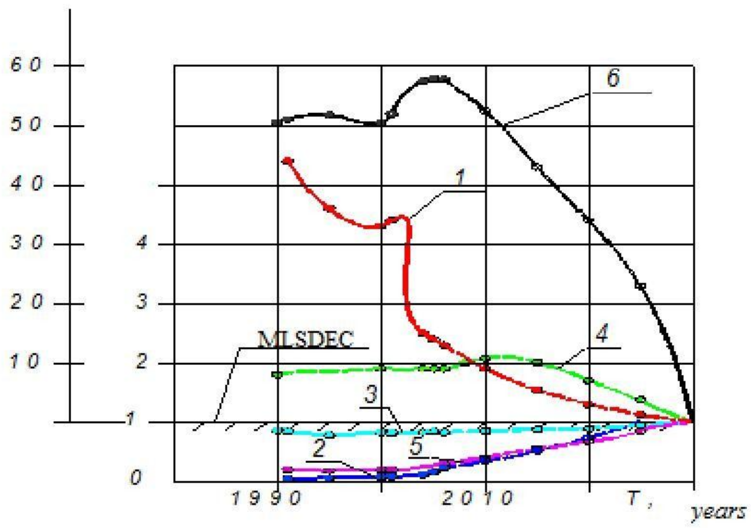

Fig. 4. Indicators of human development index and its components in the Republic of Kazakhstan for 1990-2008 with the forecast through to 2030

1 – infant mortality rate per 1,000 live births; 2 – gross domestic product per capita, US dollars; 3 – life expectancy; 4 – number of beds per 10 thous people; 5 – human development index; 6 – disease with the diagnosis set for the first time per 100 thous people.

The contradiction between the production of wealth and its distribution among the members of the company has long been there, even before the creation of the theory of surplus value. This is the reason of the increasing consumerism propaganda. Therefore, the manufacturer can't stop, even due to the understanding

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that the used natural resources are running out: soils degrade, flora is depleted, water bodies and air are heavily polluted.

The analysis of the use of natural resources shows that both their depletion and pollution take place, including the depletion and pollution of water and soil. Air is heavily polluted. The following measures must be foreseen: the existing procedure of subsidies should be reviewed, i.e. it is necessary to subsidize the measures that lead to increased returns on natural resource use. For example, the increasing crop yields or the results like increasing return on the use of water resources, which in turn depend on improving the quality and humus of the soil, or on improving the eco-reclamation state of irrigated area, or the measures contributing to improving the quality of the environment, not the volume of use of natural resources.

There is no economic mechanism of protection of social issues and the environment. The reasons are lack of the appropriate criteria for substantiation of the socio-ecological-economic efficiency of the use of natural resources and lack of interest of consumers in their rational use.

No incentives for the production of goods and services for communities are created (roads, dams, public transport, education, health, etc.) The market is focused not on the production of the socially necessary goods but on meeting the demands of those who have money. Worthy of attention is the proposal to introduce special differentiated tax from every worker in accordance with the size of salaries and the establishment of a special endowment fund. This simultaneously addresses issues of healthcare: babies and elderly homes can be kept at a high level, it can contribute to the accumulation of the necessary funds for the sick, treatment of diseases which require assistance of foreign experts, etc.)

CONCLUSION

The fundamental principles of the infinite management of rational use:

- for non-renewable resources is compliance with the conditions of the economical use and preventing pollution. To find their substitutes is the most important.
- for non-depletable resources is compliance with the condition of preventing pollution during their use.

At the current level, the global problem of climate warming [17, 18, 19, 20, 21, 22, 23, 24] or colder climate is added to the above problems. [25]

As noted, to this day a lot of attention was paid to changes in temperature regime and the rise in water level in the oceans. Considerable research on the effects of some of these phenomena, such as changes in rainfall and the threat of more intense floods and droughts, was devoted to them. However, almost no studies were carried out to ascertain the magnitude of the potential impacts of climate change on water resources at the regional, national or local level. IPCC projected [17,18] that relatively small change in air temperature, for just a few degrees, would increase the water flow and water supply to 10-40% in some areas, while in others they would be reduced by 10-30%.

For example, the most important directions of the state economy policy of Russia in relation to climate change [21] is assessment of the impact of climate change that requires adaptation measures. At the same time, the decision for adaptation is taken based on the analysis of the present and the expected development of the technical industries (energy, construction, transportation, utilities, etc.) The development of these sectors is determined by the currently adopted strategies through to 2020, and for some sectors – up to 2030.

In particular, the purpose of the implementation of adaptation measures into national policies and programs associated with climate change in the Chu-Talas transboundary basin [22] is reduction of security risks associated with climate change by enhancing adaptive capacity in this transboundary basin. The joint assessment of environmental vulnerability is assumed with a focus on selected areas (sectors), which is of particular importance for the activity of Water Commission, as well as development of a package of possible adaptation measures and procedures for the Commission, which will help mitigate the potential stress due to changes in the water regime [26].

Common possible consequences of global warming are as follows:

1. Annual river flow in the initial period of global warming will be slightly increased – apparently, until the increase in temperature is stopped or the stocks of perpetual snow or ice run out; the parameters of the maximum and minimum flow will also change [27, 28].

2. The needs of water users in water and especially of the irrigated agriculture will increase. It will last until the increase in temperature is stopped. These effects may affect the placement of agricultural and fruit crops, i.e. the specialization of placement of the economy sectors, etc. It may be that the heat-loving varieties of crops can be grown in the areas closer to the northern regions, and, vice versa, sand encroachment can be observed in the southern regions, etc.
3. Hence, there are other related problems:

- for transboundary rivers (depletion and pollution, water allocation, maintenance of hydraulic structures, damages, payment for water, new methods of socio-ecological-economic efficiency of water management and protection measures, etc.); [29].
- for a local flow (similar problems except for payment for water).

Thus, it will require to develop special measures for adaptation to climate change. There are many definitions of the term "adaptation to climate change", but they all boil down to the following: adaptation to climate change refers to adjustment of natural or human systems in response to actual or expected impacts of climate change or its effects, which moderates harm or exploits beneficial opportunities. It is obvious that, when speaking about adaptation as a deliberate and purposeful response to climate change, you first of all should pay attention to the adaptation measures implemented in order to reduce the adverse effects of climate change for anthropogenic systems. In this regard, it is necessary to allocate such adaptations as preventive adaptation (adaptation that takes place before the manifest of the consequences of climate change), autonomous adaptation (adaptation that does not constitute a conscious response to climatic stimuli and is caused by ecological changes in natural systems and changes in markets), planned adaptation (adaptation that is the result of a deliberate decision on actions based on awareness of the fact that climate has changed and certain measures must be taken to return to the original or other desired state) [30, 31].
In the future, it is necessary to develop a "National program of measures to mitigate the effects of climate change through to 2020 and further for 2050-2100". Problems of adaptation to climate change will be considered in our future research.

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