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WATER AVAILABILITY IN WATER-ECONOMIC BASINS IN KAZAKHSTAN AND THEIR ANTHROPOGENIC TRANSFORMATION

Water is one of the most important natural resources. The water availability and scarcity depend on various natural and anthropogenic factors. On the basis of generalization and analyses of the numerous cartographic materials, the water-economic basins (WEBs) in Kazakhstan were classified in order to identify the basin affected by human activities the most. Additionally, the water supply (availability) in the WEBs was determinated by share (%) of water resources (rivers, lakes, water reservoirs). The Zhaiyk-Caspian WEB has the highest share (94%) of river water. By water resource (43.8 km^3), the Ertis WEB is the most water-rich basin. A significant anthropogenic transformation was observed in the Aral-Syrdarya and Esil WEBs. Both basins are characterized by water pollution and a deteriorated water quality.

Key words: water resources, water-economic basins, water availability, Kazakhstan.

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Водообеспеченность в водохозяйственных бассейнах Казахстана и их антропогенная трансформация

Вода является одним из важнейших природных ресурсов. Водообеспеченность и дефицит воды зависят от различных природных и антропогенных факторов. На основе обобщения и анализа многочисленных картографических материалов водохозяйственные бассейны (ВХБ) в Казахстане были классифицированы для того, чтобы наиболее точно определить бассейн, где деятельность человека преобладает. Кроме того, водообеспеченность в водохозяйственных бассейнах определялось по доле (%) водных ресурсов (рек, озер, водохранилищ). Наивысшая доля (94%) речной воды имеется в Жайык-Каспийском ВХБ. Ертисский ВХБ является самым богатым водным бассейном и водные ресурсы составляют 43,8 км^3. Значительная антропогенная трансформация наблюдалась в Арало-Сырдаринском и Есилском ВХБ. Оба бассейна характеризуются загрязнением воды и ухудшением качества воды.

Ключевые слова: водные ресурсы, водохозяйственный бассейн, водообеспеченность, Казахстан.

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Қазақстанның су-шаруашылық алаптарының сумен қамтылуы және олардың антропогендік трансформациясы

Су – ең маңызды табиғи ресурстардың бірі болып табылады. Сумен қамтылу және су тапшылығы түрлі табиғи және антропогендік факторларға тәуелді болады. Көптеген картографиялық мәліметтерді қорыту және талдау негізінде Қазақстандағы су-шаруашылық алаптары адам әрекеті басым жерлерін нақты анықтау үшін жіктелді. Сондай-ақ, су-шаруашылық алаптарының сумен қамтылуы су ресурстарының (өзендер, көлдер, суқоймалар) үлесі бойынша анықталды. Өзен суларының ең көп үлесі (94%) Жайық-Каспий су-шаруашылық алабында. Ертіс су-шаруашылық алабы ең суға бай алап болып табылады және су ресурстары 43,8 км^3 құрайды. Айтарлықтай антропогендік трансформация Арал-Сырдария және Есіл су-шаруашылық алаптарында байқалды. Екі алап та судың ластануы және су сапасының нашарлауымен сипатталады.

Түйін сөздер: су ресурстары, су-шаруашылық алабы, сумен қамтылу, Қазақстан.

Introduction

Water is the most important natural resource and without it no human activity is possible as it cannot be replaced by anything. Water resources are integral parts of the natural environment and they play a decisive role in the economic development, especially in the agricultural-industrial complex.

Kazakhstan belongs to the category of countries with a large water shortage. In terms of water availability, Kazakhstan ranks last among the CIS countries. The specific water availability is 37 thousand m^3 per 1 km^2 and 6.0 thousand m^3 per 1 person per year (Duskayev 2004). The water availability in the Central Asian countries is very uneven. It is 5.7 thousand m^3 for five Central Asian countries. The average annual water availability per capita is 13.5 thousand m^3 in Tajikistan and 8.4 thousand m^3 in Kyrgyzstan and Uzbekistan and Turkmenistan is 1.8 and 4.0 thousand m^3/capita, respectively (Mal'kovskii 2012; Zaurbek et al. 2012). In Russia, it is about 30.0 thousand m^3/capita (Boiarkina, 2011).

The scarcity of fresh water is the most acute environmental problem that hinders the sustainable development of Kazakhstan (Espolov et al. 2006). The reasons for the lack of water resources are natural conditions (90% of spring runoff) and that about half of the river runoff (44.0 km^3) is formed in the territory of neighboring countries: China (18.9 km^3), Uzbekistan (14.6 km^3), Russia (7.5 km^3), and Kyrgyzstan (3.0 km^3) (Riabtsev et al. 2004). Only 56.5 km^3 of the runoff are formed on the territory of Kazakhstan, while the total average of 100.5 km^3/year of surface water resources in Kazakhstan. So, the geographical location of the country is one of the most important factors in water shortage. The surface water resources are extremely unevenly distributed across Kazakhstan and they are subject to significant temporary fluctuations (Espolov et al. 2006; Mal'kovskii 2012).

The population of Central Asian countries has increased over the past decades and the problem of water scarcity has become even more acute respectively. Consequently, the demand for water rapidly has grown and as a result of the reduction of sustainable water supplies, a water deficit of 14 billion m^3 is expected by 2030, by 2050 the deficit could be 20 billion m^3 (70% of the demand for water) (Green Economy, 2013). In addition, the climate in most parts of Central Asia is arid and semi-arid. This is especially true for southern Kazakhstan, where the limited precipitation (up to 130 mm) can easily lead to water shortages (Gagloeva 2016; Danilov-Danilian 2008; Danilov-Danilian et al. 2010). Besides many water sources are polluted with industrial wastewater as water treatment is still limited in its regional coverage and efficiency (Espolov et al. 2006; Riabtsev et al. 2004; Dostai 2012). In general, the quality of surface waters is considered good, although a number of river/water basins are contaminated. Mining, metallurgical and chemical industries, and municipal services of cities are the main sources of water pollutants (Dostai 2012; Sarsembekov 2004). As a result of the deterioration of the quality of natural waters in Kazakhstan, the problem of providing the population with good-quality drinking water is increasing. This leads to an increase in infectious morbidity, the emergence

of environmental refugees and the growth of social tension (Espolov et al. 2006).

The scarcity of fresh water and the deterioration of the water quality hinder the sustainable development of the country and cause environmental issues (Dostai 2012). The problems of sustainable water supply in the Central Asian countries are currently acquiring an acute socioeconomic, ecological and political dimension, which is due to the increasing role of anthropogenic factors related to water consumption for the needs of the population, industry and agriculture on the one hand, and the impact of the climate change on the other hand (Kulmatov 2014; Medeu et al. 2012; Alamanov 2016; Muhabbatov 2016; Veisov and Khamrayev 2016; Khamrayev and Rahimov 2016).

Assessment and forecast of changes in water resources due to the expansion of economic activities and climate change; water resources management and modeling; harmful impacts on water resources; and international cooperation in the field of water issues are modern topical hydrological aspects in Central Asia and the adjacent countries. The main purpose of this paper was the assessment of the water resources within the water-economic basins (WEBs) in Kazakhstan, as well as to classify the WEBs by their anthropogenic transformation.

Study area

The research was conducted in the water-economic basins (WEBs) within Kazakhstan (Fig.1). The WEB is a natural-anthropogenic complex of interconnected natural objects and engineering and technical facilities that jointly function to meet the various water-related socio-ecological and economic needs of people, as well as the rational management of which provides a safe and sustainable ecologic-economic development. The basin is a managed system of social, economic, technical, legal and ecological relationships regarding rational water use (Abdukhalikov, 2015).

There are eight water-economic basins in Kazakhstan such as Aral-Syrdarya, Balkash-Alakol, Ertis, Zhaiyk-Caspian, Esil, Nura-Sarysu, Shu-Talas and Tobyl-Torgai basins (Table 1, Fig.1). The Ertis WEB has with 43.8 km³ the biggest share (%) of the water resources. The Tobyl-Torgai WEB is the basin with the smallest share of the water resources (2.9 km³) (Duskayev 2004). The largest WEB in Kazakhstan is the Zhaiyk-Caspian basin with an area of 415 thousand km² (Table 1). River water is 94 %, the share of water reservoirs is 3 % and groundwater is 3 % in the basin (Duskayev 2004).

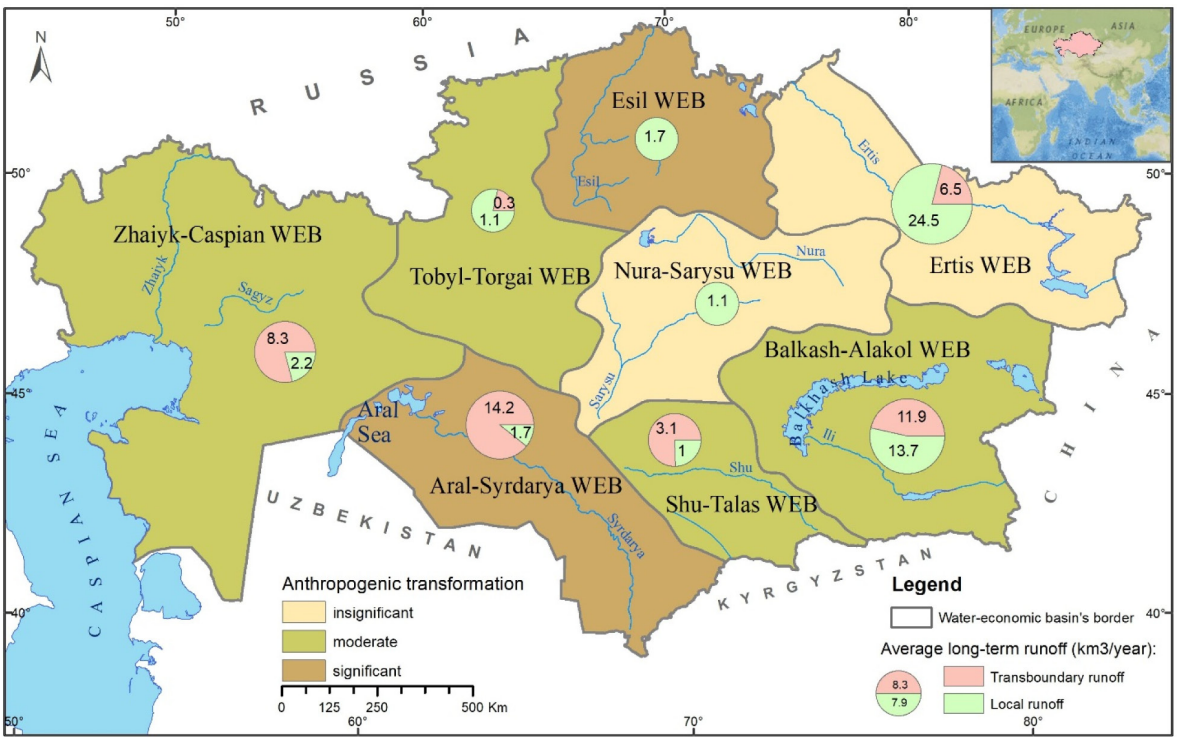

Fig.1 – Study area – the main water-economic basins (WEB) in Kazakhstan

Table 1 – The main characteristics of water-economic basins

Basins	Basin area, thousand km^2	Main River	Flow formation, %	Population within basin, mln people		% from total population in Kazakhstan	Mean long-term runoff, km^3
				Urban	Rural		
Aral-Syrdarya	345	Syrdarya	75.2 in Kyrgyzstan 15.2 in Uzbekistan 6.9 in Kazakhstan 2.7 in Tajikistan	1.3	1.5	16	From 11.3 to 27.8
Zhaiyk-Caspian	415	Zhaiyk	8 in Kazakhstan 92 in Russia	2.2		13	
Balkash-Alakol	353	Ile	56.6 in Kazakhstan 43.4 in China	1.8	1.5	19	From 27.8 to 33.8
Ertis	1643	Ertis	74 in Kazakhstan 26 in China	3.7		23.4	
Esil	245	Esil	100 in Kazakhstan	1.09	0.81	11	From 2.2 to 11.3
Shu-Talas	64.3	Shu, Talas	24 in Kazakhstan 76 in Kyrgyzstan	1.0		5.8	
Nura-Sarysu	139.7	Nura and Sarysu	100 in Kazakhstan	1.0		5.8	From 1.3 to 2.2
Tobyl-Torgai	214	Tobyl	78 in Kazakhstan 22 in Russia	1.05		6	

Materials and methods

The water availability in Kazakhstan differs significantly. The East Kazakhstan region is a water-rich region within the Ertis WEB, and there are regions where water is scarce such as Mangystau region. The water availability and state of water resources within WEB in Kazakhstan was considered and analyzed in this paper. In addition, numerous cartographic materials (three maps from NAKZ, 2010) related to the anthropogenic disturbance of the WEBs were analyzed in order to classify the category of anthropogenic transformation within the WEBs in Kazakhstan.

The Arc map software was used as a main tool to analyze the anthropogenic impact to the WEBs as well as for preparing the map of anthropogenic transformation of WEBs within Kazakhstan.

The original map with the border of WEB was scanned and registered/geo-referenced to specify its location by using vector layer of country's border. Thereafter, the collected data for average long-term runoff, anthropogenic transformation and water demand were given as input parameters for the generation of maps using ArcGIS applications.

Results and discussion

A share of water resources in the WEBs and water supply (availability)

In dry years, the level of water supply is 60% of the water demand, and for some regions such as Central Kazakhstan is only 5-10% due to mainly irrigated agriculture.

The Ertis WEB is the most water-rich basin. The water resource is 43.8 km^3. A river flow form the main water reserves with volume of 26.04 km^3 that is 59% from basin water (Table.2). The volume of water reservoirs is 7.7 km^3 (18%) and is the largest basin in Kazakhstan where there are powerful water reservoirs are located (Table.2).

The water resource in the Balkash-Alakol WEB is significant and amounts to 149.4 km^3, however the main volume (77%) of water is in lakes, mainly in Lake Balkash. The share of river water is 14% and water reservoirs is 5% in the basin.

The water resources of the Aral-Syrdarya WEB are estimated 37.9 km^3. The main volume of the runoff which is 70% is formed in the upper part of the basin until the outlet from the Fergana Valley. The flow of right-bank tributaries above

the Shardara water reservoir is 21-23% of the total water resources flowing into Kazakhstan (Table.2). The share of the Arys river runoff and other rivers flowing from the Karatau range in Kazakhstan is 9-7% (Riabtsev 2004). Currently, there are about 100 water reservoirs and 24,000 km of irrigation canals in the Aral Sea basin (Bogomolov et al., 2007).

A share of river water accounts for 94% in the Zhaiyk-Caspian WEB (Table.2). This WEB has the highest share of river waters among the rest WEBs.

The water availability of Kazakhstan varies significantly. There are high-water supply regions such as East Kazakhstan region (Ertis WEB). The Ertis WEB is rich in water availability as half of its renewable water resources are generated in the Kazakh part of the catchment (Abishev et al. 2016) and it is used as a donating water basin during times of water shortage (Table 2). Significant water resources are also concentrated in the Aral-Syrdarya and Balkash-Alakol WEBs (Table 2).

Table 2 – A share of water resources in the water-economic basins

Water-economic basins	Water resourceskm^3	Share of rivers, %	Share of lakes, %	Share of water reservoirs, %	Share of groundwater, %	Large Water reservoir	
						Name	Volume km^3
Aral-Syrdarya	37.9	70	-	21-23	7	Shardara	5.2
Zhaiyk-Caspian	28	94	3	3	3	-	-
Balkash-Alakol *	149.4	14	77	5	4	Kapshagai	14.0
Ertis	43.8	59	16	18	7	Bukhtyrma	49.0
Esil	5.34	34	55	7	4	Viaches-lavskoye and Sergeev-skoye	0.4 and 0.7
Shu-Talas	6.11	59	6	8	27	-	-
Nura-Sarysu	4.59	33	20	4	25	-	-
Tobyl-Torgai	2.9	35	33	17	15	Verhne-Tobolskoye and Karatomar	0.82 and 0.59

*Notice: the main volume (77%) of water is concentrated mainly in Balkash lake.

Quality of surface water and Anthropogenic impact to the WEBs in Kazakhstan

Water quality is one of the limiting factors for sustainable development of Kazakhstan. The water quality of almost all water basins in Kazakhstan remains unsatisfactory, despite the decline in production and the reduction in the volume of wastewater discharged. The main pollutants enter water bodies with waste waters from chemical, oil-refining, machine-building and non-ferrous metallurgy sectors. Contaminated sewage waters discharged without any purification are the greatest environmental threats to the water bodies.

Kazakhstan is located on zones of transit and dispersion of flow, as well as on delta zones of large water basins such as Syrdarya, Ile, Zhaiyk and Ertis. Since the runoff of almost all rivers is regulated, the regime of runoff formation in river parts located below the water reservoirs is strongly transformed. As a result of the mutual impact of rivers and catchment areas and intensive water use, the hydrological regime and the water quality change in the zone of flow transit and dispersion. This mutual impact is characterized by intensive water abstraction from rivers for industry and irrigated agriculture and the discharge of return flow with salts, chemicals and other contaminants into rivers (Espolov et al. 2006; Riabtsev 2004; Dostai 2012).

The water quality in the Aral-Syrdarya WEB can be classified as the fourth to the sixth class of water pollution and overall it is considered to be a highly-polluted WEB. The main pollutants in this basin are

nitrogen, sulfate, cupper and phenol. The maximum pollution was observed in spring, when nitrite and copper exceed the maximum allowable ratio (MAR) by the factor 3 (with mean concentration of 0.08 mg/l and 0.001 mg/l respectively), while sulfate exceeds the MAR by the factor 7 (100 mg/l), phenol by the factor 6 (0.001 mg/l), and oil products by the factor 4 (0.05 mg/l) (Riabtsev 2004). The main tributaries of the Syrdarya river and the Shardara water reservoirs are also polluted by those chemicals. The surface waters of the Ertis WEB are contaminated with heavy metals such as zinc and copper and the Ertis has been sorted into the fourth pollution class. The main pollutants in the Zhaiyk-Caspian WEB are organic matter, boron and chromium and the sources for this contamination are located in the Russian part of the catchment as there are no wastewater discharges into the mainstream within Kazakhstan. The resulting pollution class for the Zhaiyk-Caspian basin is 4-6 (Riabtsev 2004). The main pollutants in the Lake Balkash are heavy metals, copper, zinc, phenol, fluorides and oil products, but overall the basin belongs to moderate class of pollution. In addition, the surface water in the Ile basin is polluted by oil products originating in the upper Chinese catchment (Dostai 2012). The pollution with heavy metals is a common problem for rivers in the Nura-Sarysu basin. The main metallurgical factories and coal basin of the country are concentrated within basin. That's why water resources of the basin were polluted by wastewaters. The water quality of the basin is estimated to fourth class of water pollution. The pollution degree of the surface waters in the Esil and Tobyl-Torgai basins are significantly lower and the water quality class only shows a moderate level of pollution (Espolov et al. 2006; Riabtsev 2004).

The chemical pollution of waters of open water bodies has significantly increased during the last several decades. There is a high coefficient (56.8 %) of pollution in the Kyzylorda region (Aral-Syrdarya WEB), 16.7 % in the West Kazakhstan region (Zhaiyk-Caspian WEB), in Karagandy region is 15.6 % (Nura-Sarysu WEB), in Akmola region is 15 % (Esil WEB) (Espolov et al. 2006). The quality of the surface water largely depends on the ecological situation and the economic development of the region. The anthropogenic activities negatively affect the regional ecological situation and cause enormous changes in the environment.

According to the anthropogenic transformation of the river flow, river basins are divided into three classes such as slight, moderate and significant. The Aral-Syrdarya and Esil WEBs belong to the significant class of the anthropogenic transformation. The moderate class includes the Zhaiyk-Caspian, Tobyl-Torgai, Shu-Talas and Balkash-Alakol WEBs. The remaining two WEBs: the Nura-Sarysu and the Ertis are included in the class of only slight anthropogenic transformation (Fig.2). The most affected by human influences is Aral-Syrdarya WEB (47%); 23 % of the territory of the Esil WEB was deteriorated by human activities. The Zhaiyk-Caspian and Tobyl-Torgai WEBs were affected by human activities to 18 % (Fig.2).

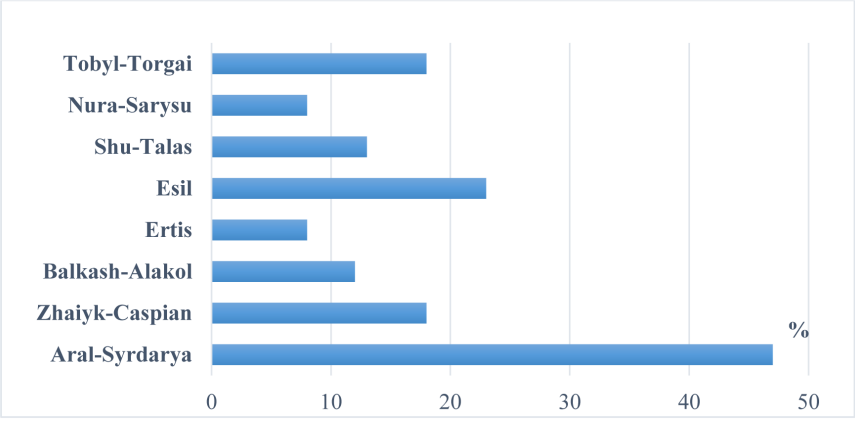

Fig. 2 – Anthropogenic transformation of water-economic basins in Kazakhsta**n**

Conclusion

Water resources are the main component of the environment and play a decisive role in the development of all sectors of country's economy. The study of water availability and the state of water resources within water basins in Kazakhstan

allows the general assessment of the conditions and current state of the water-economic basins in Kazakhstan. During the last several decades, natural factors and human activities have changed the Kazakh landscape considerably, including its water resources. Consequently, the water resources were polluted and water quality was deteriorated. The Aral-Syrdarya and Esil WEBs are the most affected by the direct anthropogenic factors and consequently waters of the basins are highly polluted.

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