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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
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Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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GIS-ASSESSMENT OF GROUNDWATER SUPPLY TO POPULATION AND BRANCHES OF ECONOMY OF KAZAKHSTAN WITH ACCOUNT TO LONG-TERM WATER DEMAND

Abstract. Expert estimates in the Concept of Kazakhstan 2013 transition to green economy forecasted water deficit in the nearest future. The water deficit indicator is the level of water supply identified as the ratio of forecast resources or mineable reserves to water demand. The article presents up-to-date data on water demand of economy branches and urban and rural population need for drinking water, as well as estimated values of water consumption for 2030 and 2040.

Taking into consideration that groundwater as a water supply source has some advantages as compared to surface water: higher quality, more reliably protected against pollution and contamination, less exposure to seasonal and multi-annual fluctuations, the level of water supply was assessed as applied to RK groundwater.

Taking into account the fact that statistics are presented with a breakdown into administrative regions, and distribution of geological formations is not limited by borders of surface water flow basins or national frontier, GIS-assessment of groundwater resources and water demand of population and economy branches are given in this article by administrative territory system and hydro-economicadministrative zoning of Kazakhstan.

As the result of appraising the Kazakhstan administrative regions' degree of water supply, it was shown that by proven reserves of drinking and service water, the Republic as a whole belongs to countries with a reliable supply of proven drinking and service groundwater reserves, Atyrau and North-Kazakhstan regions are identified as experiencing deficit, and Mangistau and Akmola – as partially supplied.

While assessing the degree of supply within limits of hydro-economic basins a conclusion was made that the highest degree of supply with own groundwater resources has Balkhash-Alakol and Yertis (Irtysh) basins. Those experiencing deficit of groundwater is Tobol-Torgai, Nura-Sarysu, and Yesil basins.

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Key words: groundwater, GIS, water supply, water demand, cartography.

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ПЕРСПЕКТИВТІ СУ ҚАЖЕТТІЛІГІН ЕСКЕРЕ ОТЫРЫП, ҚАЗАҚСТАН ХАЛҚЫН ЖӘНЕ ЭКОНОМИКА САЛАЛАРЫН ЖЕР АСТЫ СУЫМЕН ҚАМТАМАСЫЗ ЕТУДІ ГАЖ БАҒАЛАУ

Аннотация. Қазақстанның 2013 жылғы “жасыл экономикаға” көшу жөніндегі тұжырымдамасында, сараптамалық бағалаулар, жақын болашақта су тапшылығы болатынын болжағаны көрсетілген. Су тапшылығының көрсеткіші, болжамды ресурстарды немесе эксплуатациялық су қорларын, су қажеттілігіне шағу арқылы анықталады. Бул мақалада, экономика салаларының, қала және ауыл халқының ауыз суға қажеттілігінің өзекті деректері, сондай-ақ 2030 және 2040 жылдарға арналған су тұтыну болжамы келтірілген.

Сумен қамтамасыз етілу дәрежесі, ҚР жер асты суларына қатысты бағаланған. Оған негізгі себеп, сумен жабдықтау көзі ретінде, жер асты суларының, жер үсті суларымен салыстырғанда бірқатар артықшылықтары бар екендігінде. Атап айтқанада: сапасы жақсы, ластанудан және зақымданудан сенімді қорғалған, маусымдық және көпжылдық ауытқуларға бейімі аз.

Статистикалық деректер әкімшілік облыстар бойынша ұсынылғанын, ал геологиялық формациялардың таралуы жер үсті су бассейндерінің немесе ұлттық шекаралармен шектелмейтінін назарға ала отырып, осы мақалада ГАЖ-жер асты сулары ресурстарын және халық пен экономика салаларының су қажеттілігін бағалау, Қазақстанның әкімшілік-аумақтық жүйесі және су шаруашылығыәкімшілік аудандастыру бойынша келтірілген. Қазақстанның әкімшілік облыстарының қамтамасыз етілу дәрежесін бағалау нәтижесінде, шаруашылық ауызсу мақсатындағы жерасты суларының барланған қорлары бойынша, Республика тұтастай шаруашылық ауызсу мақсатындағы жерасты суларының барланған қорларымен сенімді қамтамасыз етілгендігі көрсетілді. Атырау және Солтүстік Қазақстан облыстары су тапшы облыстарға, ал Маңғыстау және Ақмола облыстары ішінара сумен қамтамасыз етілген екендігі көрсетілді.

Жер асты суларымен қамтамасыз етілу дәрежесін бағалауды су шаруашылығы бассейндерінің шекараларында жүргізу кезінде, өз ресурстарымен неғұрлым көп қамтамасыз етілген Балқаш-Алакөл және Ертіс бассейндері деген қорытынды

жасалды. Жерасты сулары бойынша су тапшы санатына Тобыл-Торғай, НұраСарысу және Есіл бассейндері жатады.

Аталған зерттеу Қазақстан Республикасы Экология, геология және табиғи ресурстар Министрлігінің қаржылық қолдауымен орындалды (№BR10262555 грант).

Түйін сөздер: жерасты суы, ГАЖ, сумен қамтамасыз ету, су қажеттілігі, картография.

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ГИС-ОЦЕНКА ВОДООБЕСПЕЧЕННОСТИ ПОДЗЕМНЫМИ ВОДАМИ НАСЕЛЕНИЯ И ОТРАСЛЕЙ ЭКОНОМИКИ КАЗАХСТАНА С УЧЕТОМ ПЕРСПЕКТИВНОЙ ВОДОПОТРЕБНОСТИ

Аннотация. В Концепции по переходу Казахстана к «зеленой экономике» 2013 года экспертными оценками прогнозировался в ближайшем будущем дефицит воды. Показателем дефицита воды является степень водообеспеченности, определяемая как отношение прогнозных ресурсов или эксплуатационных запасов к водопотребности. В статье представлены актуальные данные водопотребности отраслей экономики и потребности городского и сельского населения в питьевой воде, а также прогнозные значения водопотребления на 2030 и 2040 гг.

Учитывая, что подземные воды как источник водоснабжения имеют ряд преимуществ по сравнению с поверхностными водами: обладают лучшим качеством, более надежно защищены от загрязнения и заражения, меньше подвер жены сезонным и многолетним колебаниям, водообеспеченность оценена применительно к подземным водам РК.

Принимая во внимание, что статистические данные представлены в разрезе административных областей, а распространение геологических формаций не ограничивается пределами бассейнов стока поверхностных вод или национальных границ, ГИС-оценка ресурсов подземных вод и водопотребности населения и отраслей экономики в данной статье приведены по административнотерриториальной системе и водохозяйственно-административному районированию Казахстана.

В результате проведенных оценок степени обеспеченности административных областей Казахстана показано, что по разведанным запасам подземных вод хозяйственно-питьевого назначения республика в целом относится к надежно

обеспеченным разведанными запасами подземных вод хозяйственно-питьевого назначения, Атырауская и Северо-Казахстанская области отнесены к дефицитным, а Мангистауская и Акмолинская – к частично обеспеченным.

При проведении оценки степени обеспеченности в границах водохозяйственных бассейнов сделан вывод, что наиболее обеспеченными собственными ресурсами подземных вод являются Балкаш-Алакольский и Ертисский бассейны. К дефи цитным по подземным водам относятся Тобол-Торгайский, НураСарысуский и Есильский бассейны.

Данное исследование выполнено при финансовой поддержке Министерства экологии, геологии и природных ресурсов Республики Казахстан (грант № BR10262555).

Ключевые слова: подземные воды, ГИС, водообеспеченность, водопо требность, картография.

Introduction. The development of Kazakhstan's fresh groundwater resources has high priority in the resolving of water deficit issues specified in the Strategy "Kazakhstan – 2050" as one of today's global challenges.

The main purpose of the water resources utilization system of the Republic of Kazakhstan (RK) is the provision of quality water to the population and all branches of the economy, the creation of favorable conditions for their operation, and water resources protection against depletion and pollution.

The implementation of the 2021-2025 Republic of Kazakhstan Concept of Water Resources Management System Development focuses on achieving strategic indicators of the Republic of Kazakhstan National Development Plan, including based on water resources conservation as a component of the environment and as a naturally renewable resource required for ensuring vital activity of the population and branches of economy.

Activities aiming at ensuring water resources sound management and protection are determined in the basinal scheme of water resources integrated management and protection; the master scheme of water resources integrated management and protection identifies key hydro-economic and other activities throughout the country in general that are to be carried out to satisfy long-term needs of the population and economy branches in the water.

Taking into account the fact that water basins are not concentrated within individual administrative regions, and distribution of geological formations is not limited by borders of surface water flow basins or national frontier, assessment of groundwater resources and water demand of population and economy branches in this article is given by administrative territory system and hydro-economic basins (HEB).

Materials and methods. Data was taken from statistical and regulatory sources containing information about water use to cover drinking and service needs in cities and rural settlements, for production and processing water supply to branches of the economy.

In the course of scientific research, hydrogeological, statistical, and geo-informational methods were applied to the assessment of the existing and estimated

water consumption by the population and branches of the economy of the Republic of Kazakhstan.

In the process of creating digital thematic maps, necessary data was prepared, mathematical calculations were made, cartographic information presentation and execution were elaborated, causative and probabilistic reasoning were performed allowing making logical conclusions and analyzing results.

Any territory groundwater formation depends on a large variety of factors, including those of primary importance – geological and structural, and lithologic features of water-bearing strata, as well as climatic characteristics of the region (Gleeson et.al, 2020; Bierkens et.al, 2019; Osipov et.al, 2019).

The degree of water supply level is identified as the ratio of forecast resources or mineable groundwater reserves to the need for freshwater as shown by formulae (1-2).

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$$К = Q_{gwmr}/W_{needs} \quad (1)$$

$$К = Q_{gwfr}/W_{needs} \quad (2)$$

where: К − factor of the level of drinking and service groundwater supply;

Q_{gwmr} − value of groundwater mineable reserves;

Q_{gwfr} − value of groundwater forecast reserves;

W_{needs} − the region's need in drinking and service water.

The general assessment of the territory level of supply with water resources or "water deficit indicator" – is the ratio of the total volume of available resources to water volume taken from sources.

The assessment of the level of supply with groundwater forecast and mineable resources was carried out with a breakdown by hydro-economic basins and RK administrative regions.

1. Level of water supply by RK administrative-territorial division. Hydroeconomic-administrative zoning is based on a hydrographical division of the territory into major river hydro-economic basins. Hydrographically, eight river hydro-economic basins were identified in Kazakhstan: Aral-Syrdarya, Balkhash-Alakol, Yertis, Yesil, Zhaiyk-Caspi, Nura-Sarysu, Tobol-Torgai, and Shu-Talas. By administrativeterritorial division, there are 14 regions in Kazakhstan at present: Akmola; Aktyubinsk; Almaty; Atyrau; East-Kazakhstan; Zhambyl; West-Kazakhstan; Karaganda; Kostanai; Kyzylorda; Mangistau; Pavlodar; North-Kazakhstan; Turkestan. In his address to the nation of Kazakhstan: NEW KAZAKHSTAN: THE PATH OF RENEWAL AND MODERNIZATION dated 16.03.2022, the President - Kasym-Zhomart Tokaev instructed the Government to explore issues of the administrative-territorial system and propose ways to implement the initiative of three new regions formation - Abai, Ulytau, and Zhetysu.

The total value of RK groundwater explored reserves is 44,388 thousand m^3/day, including: in Akmola region – 506.53; Aktyubinsk – 1,957.96; Almaty – 17,169.81; Atyrau – 263.85; East-Kazakhstan – 6,562.23; Zhambyl – 4,739.16; West-Kazakhstan – 375.14; Karaganda – 2,962.2; Kostanai – 1,449.78; Kyzylorda – 1,564.82; Mangistau – 402.37; Pavlodar – 3,966.56; North-Kazakhstan – 222.52; Turkestan – 2,245.72 thousand m^3/day (Smolyar et.al, 2012 a).

The total value of forecast fresh and low brackishness groundwater of the Republic of Kazakhstan is 155,732 thousand m^3/day, including: in Akmola region– 3,449.1; Aktyubinsk – 9,419.7; Almaty – 47,528,6; Atyrau – 1,821.1; East-Kazakhstan – 17,211.9; Zhambyl – 22,480.8; West-Kazakhstan – 2,625.1; Karaganda – 11,877.2; Kostanai – 2,910.1; Kyzylorda – 10,854.2; Mangistau – 547.0; Pavlodar – 11,826.1; North-Kazakhstan – 1,743.2; Turkestan – 11,438.1thousand m^3/day (Smolyar et.al, 2012 b; Ministry of Ecology et.al, 2018).

Thus, for southern regions of Kazakhstan characteristics are the highest values of groundwater forecast resources predominantly with low-level salinity, whereas in submontane areas major groundwater resources are concentrated **(**Onglassynov et.al, 2019**).** Central, northern and western regions are distinguished by a low value of forecast resources. The average value of the groundwater forecast resources module for RK is 0.47 l/s/km^2. Groundwater forecast resources modules vary from 0.01 l/s/km^2 (Atyrau region) to 2.02 l/s/km^2 (Almaty region) (Yermenbay et al., 2020).

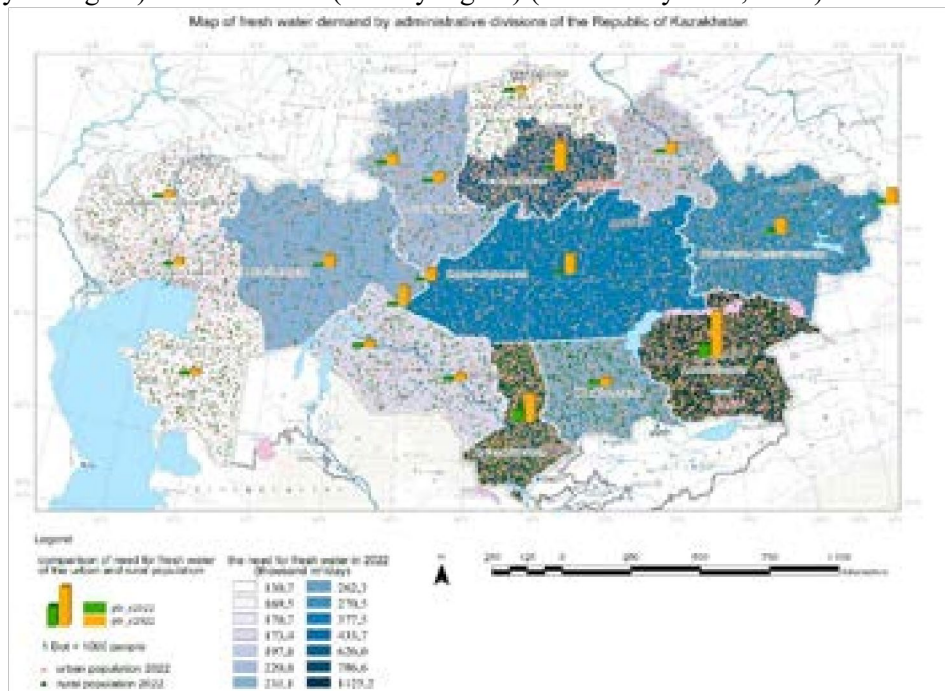

Figure 1 - Map of urban and rural population drinking water demand with breakdown into Kazakhstan administrative regions.

Based on data from the Agency for Strategic planning and reforms of the Republic of Kazakhstan Bureau of National Statistics, the country's population as of January 1 2022 year was 19125,620 people, including an urban population of 11355820 (59.37%) and a rural population 7769800 (40.63%). Population information is presented by administrative-territorial characteristics, therefore population's quality drinking water demand is also identified in the breakdown of Kazakhstan's administrative regions.

Current drinking water demand (thousand m^3/day) of the rural population is: in Akmola region– 53.8; Aktyubinsk – 35.6; Almaty – 230.8; Atyrau – 42.7; East-Kazakhstan – 70.5; Zhambyl – 96.6; West-Kazakhstan – 43.9; Karaganda – 38.3; Kostanai – 49.4; Kyzylorda – 63.8; Mangistau – 61.9; Pavlodar – 30.6; North-Kazakhstan – 39.8; Turkestan – 229.8.

Current drinking water demand (thousand m^3/day) of urban population is: in Akmola region– 572.1; Aktyubinsk – 235.0; Almaty – 894.5; Atyrau – 130.7; East-Kazakhstan – 306.9; Zhambyl – 165.7; West-Kazakhstan – 126.8; Karaganda – 395.4; Kostanai – 181.7; Kyzylorda – 134.0; Mangistau – 107.5; Pavlodar – 190.2; North-Kazakhstan – 90.9; Turkestan – 556.7.

The calculation was made based on specific daily average (yearly) water consumption per capita in population centers: in cities – 360 l/daily, in rural population centers – 140 l/daily. Unit water consumption taken (SNiP RK, 2017). Unit water consumption includes water rate for drinking and production needs and watering of streets and plants.

Figure 1 shows a built-in ArcGIS map of demand for drinking water for urban and rural populations with a breakdown by administrative regions of Kazakhstan. Population drinking water demand is highlighted by blue color on the map (the legend specifies forecast values of water consumption for 2040), and the deeper the color is, the higher the water demand indicator of a region. Green and light-yellow points schematically display population density by RK regions, and 1 point corresponds to the population of 1,000 people (demographics for 2022). The green color is identified for rural populations and light-orange – for urban. On the map, within borders of regions placed are diagrams allowing assessing water demand of the urban and rural populations.

Developments, experience, and recommendations on hydrogeological information structuring and geodata databases building in ArcGIS were taken into account while map generating (Korytny et.al, 2020).

Thus, in general, for the Republic, the population's current drinking water demand is 5,175.9 thousand m^3/day, including 4,088.1 thousand m^3/day and 1,087.8 thousand m^3/ day for urban and rural dwellers respectively, and the highest demand falls on Almaty region, the lowest – on North-Kazakhstan region as shown on the diagram (figure 2). It should be noted that mainly groundwater is used for the water supply of rural population centers throughout the Republic.

Increase in groundwater consumption until 2040 is predicted the account for the uptrend of the general water consumption due to an increase in population,

improvement of hydro-economic infrastructure condition, as well as with account to long-term plans for economic branches development (Decree of the Government of the Republic of Kazakhstan, 2013).

2. Level of water supply by Kazakhstan hydro-economic-administrative zoning. The total volume of groundwater forecast resources with breakdown into Kazakhstan hydro-economic basins is – 64.27 km^3, including Aral-Syrdarya basin – 9.29; BalkhashAlakol – 20.01; Yertis – 9.56; Yesil – 2.31; Zhaiyk-Caspi – 7.37; Nura-Sarysu – 3.32; Tobol-Torgai – 3.62; Shu-Talas – 8.79 km^3.

The total volume of groundwater known and approved reserves with breakdown into RK hydro-economic basins is – 15.44 km^3, including Aral-Syrdarya basin – 1.13; Balkhash-Alakol – 7.26; Yertis – 2.87; Yesil – 0.16; Zhaiyk-Caspi – 0.97; Nura-Sarysu – 0.82; Tobol-Torgai – 0.48; Shu-Talas – 1.75 km^3.

Thus, groundwater's largest mineable reserves are concentrated in the BalkhashAlakol basin. Yertis and Shu-Talas HEBs are characterized by groundwater considerable mineable reserves. Groundwater's lowest mineable reserves fall on Yesil and TobolTorgai HEBs.

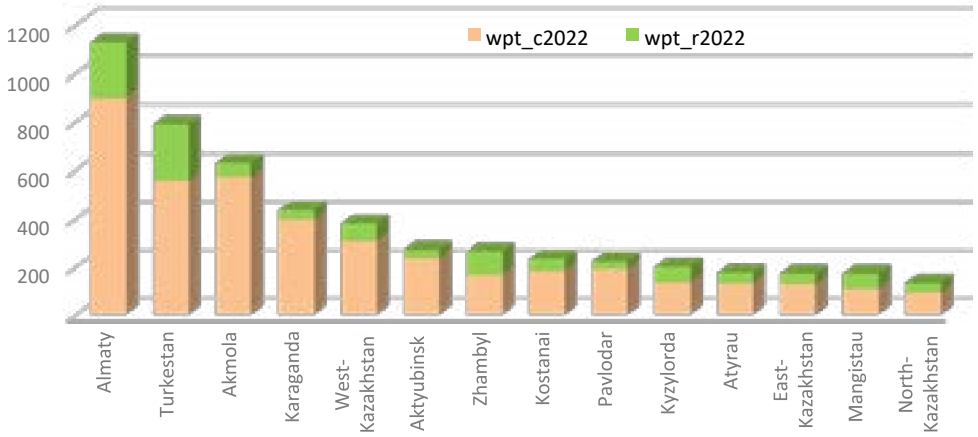

Figure 2 - Map of urban (■) and rural (■) population drinking water demand with breakdown into Kazakhstan administrative regions. 0

Water indicators and long-term water demands are assessed based on data from public accounting, water cadastre, and water bodies monitoring (Order of the Minister of Agriculture of the Republic of Kazakhstan, 2015; Toleubaeva, 2012).

Table 1 shows forecast indicators of water intake for 2040 by RK branches of the economy.

Table 1- Indicators of water intake by RK branches of economy

Branches of economy	Water intake volume for 2040, mln m^3
Regular and flood irrigation, hayfields flooding	14,687.24
Industry	5,230.65

Public utilities	1,281.97
Agricultural water supply	667.35
Fishing industry	242.14
Stock water development	152.76
Formation pressure maintenance	54.5
Recreational area etc.*	943.58

(*) The total intake by branches of the economy does not take into consideration maintaining aquifers while ensuring water intake to channels, filling the off-channel reservoir, intake of mining water without use; discharges of transboundary rivers, flow consumption for water users, and with environmental purposes.

Figure 3 shows a built-in ArcGIS map showing branches of economy water demand until 2040 in hydro-economic basins of the Republic of Kazakhstan. The water demand forecast is displayed in a red palette, and color strength characterizes the change in intensity of water demand by 2040. Within HEB limits, bar diagrams show changing demand of branches of the economy for 2020, 2030, and 2040 covered at the account of groundwater intake.

Thus, the long-term intake of groundwater to cover economic demands is estimated to be in 2030 as 6.45%, by 2040 – 7.85% of the total water intake or 40-50% of the value of the explored reserve. Diagram in figure 4 shows that the main intake of water resources with the breakdown into branches of the economy falls on agricultural water consumption (flood and regular irrigation, flooding of hayfields). Some waterconsuming agricultural sectors are separated into individual lines.

Second, in water resources, consumption by branches of the economy is industry (22%). Water consumption rate is identified as applied to production technique and water quality. Water is consumed predominantly on account of fresh surface water (89.8% of the total water intake) and partially at the account of underground sources (10.2%). Annual water intake is increased because of the oil-and-gas production and processing industry, this same branch makes the largest contribution to environmental pollution (Mukhamedzhanov et.al, 2020).

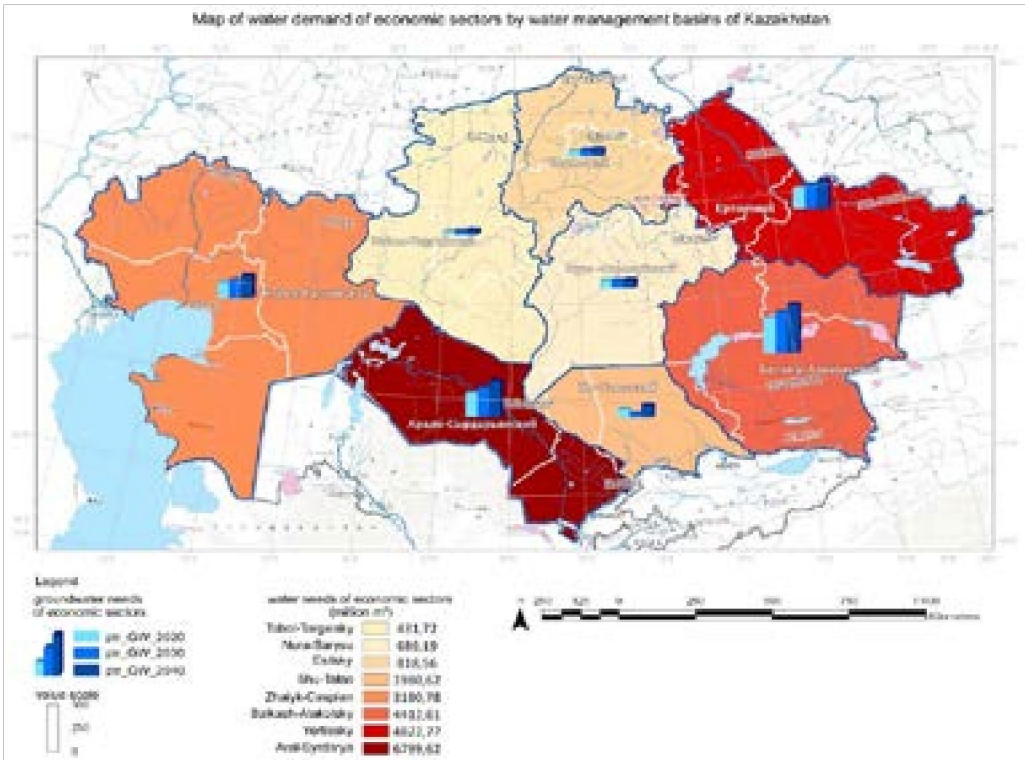

Figure 3 - Map of water demand of branches of the economy by Kazakhstan hydro-economicadministrative zoning.

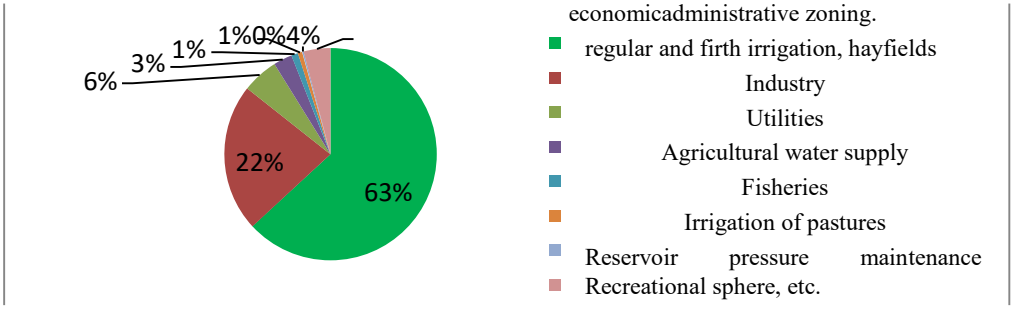

Figure 4 - Indicators of water intake by RK branches of economy, %

To minimize groundwater pollution and the consequences of its migration, it is necessary to promptly evaluate the scale of surface contamination with a determination of probability and speed of a pollutant ingress into the groundwater level. A geological environment rehabilitation expert system was developed for such evaluation. This system allows not only calculations but also recommends the most effective economic and environmental methods to clean natural complexes from oil contamination (Absametov et.al, 2017; Khaustov et.al, 2015; Shagarova et al., 2016).

Results and Discussion. Figure 5 shows a matrix of dot charts generated based on data of 14 RK administrative regions to analyze the strength of the connection between

population (urban, rural, total) freshwater demand with other parameters: values of groundwater explored reserves, values of forecast resources of fresh and low-level salinity groundwater, areas of administrative regions, population with breakdown into Kazakhstan regions. As the charts show, perfect correlation (R2=1) corresponds to a linear connection between water demand and population number within borders of all administrative borders. The lowest dependency ratio of population water demand is associated with the areas of administrative regions.

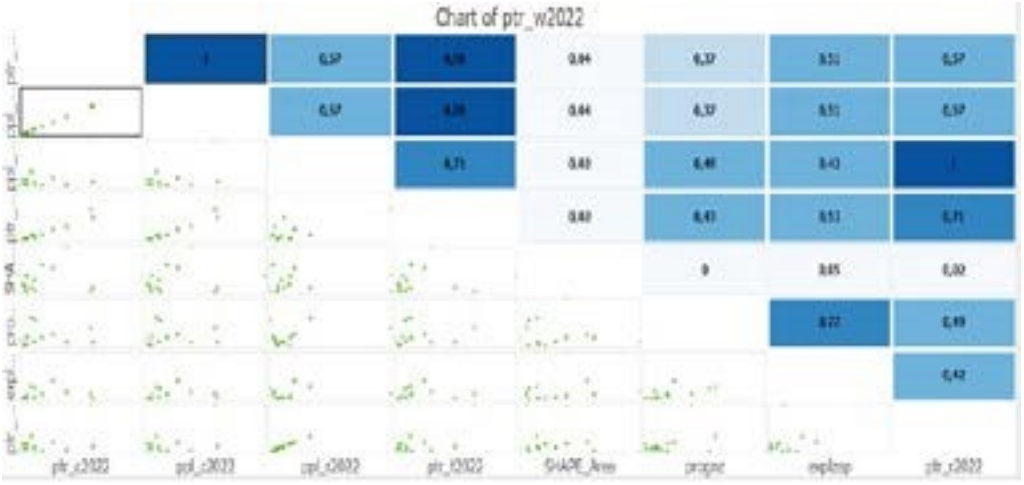

Figure 5 - Matrix of dot charts by administrative-territorial division.

Figure 5 shows the matrix of dot charts generated for 8 RK hydro-economic basins for evaluating regression degree between branches of economy water demand in general and in groundwater for 2020, 2030, and 2040. As the charts show, simple regression (R2=0.75) is mainly observed within HEB borders, the exclusion is Balkhash-Alakol HEB, for which 516.38 m^3 groundwater intake was forecasted by 2040 with this basin's branches of economy water demand estimated as 4412.6 m^3.

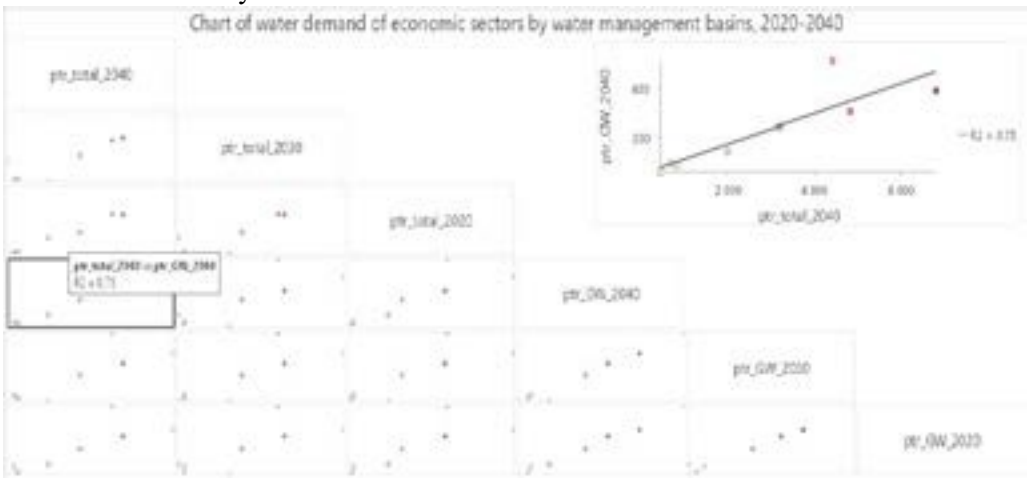

Figure 6 - Matrix of dot charts with breakdown into hydro-economic basins.

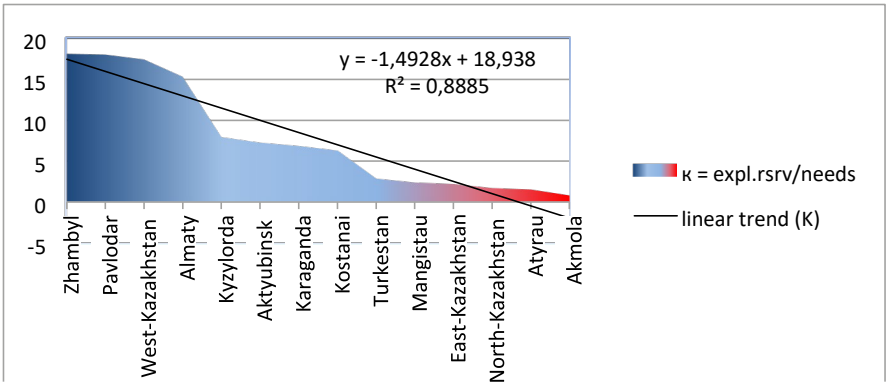

Figure 7 - Indicator of the degree of provision of the administrative regions of Kazakhstan with explored groundwater reserves.

Conclusions. The performed assessments of the level of Kazakhstan administrative regions' levels of supply with known drinking and service groundwater reserves resulted in including Akmola and Atyrau regions into the category of facing a deficit, and Mangistau and North-Kazakhstan – to partially supplied. The remaining regions and the Republic as a whole belong to the category of reliably supplied with known drinking and service groundwater reserves. It should be noted that in previous assessments, the Akmola region did not fall into the category of deficient ones; the change was caused by an increase in consumption due to the growth in the population of Nur-Sultan (Koldobskaya, 2022).

While assessing the level of supply within HEB limits, one can conclude that regions with the highest level of supply with their groundwater resources are the BalkhashAlakol and Yertis basins. Those experiencing deficit of groundwater is Tobol-Torgai, Nura-Sarysu, and Yesil basins.

The needs of the population in water resources depend on the cumulative impact of such factors cumulative impact of such factors as demographic increase, socioeconomic development and changing consumption patterns. Thus, a decrease of 50 l/day contributes to the general improvement of the forecast situation. water consumption of the urban population (59.4% of the total population) compared to the norms of 2020, the introduction of water-saving technologies in agriculture, and other sectors of the economy of the Republic of Kazakhstan.

Joint use of surface water and groundwater seems to be advisable. The tendency of the maximum possible use of groundwater for drinking water supply to the population, especially in connection with becoming more frequent cases of unforeseen (emergency) contamination of surface water sources grows at present as determinative in the global strategy of increasing reliability of utility and freshwater supply systems.

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