The dynamics of the Akhangaran basin's groundwater level in relation to physical-geographical and anthropogenic factors

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Abstract. This article describes the physical and geographical factors of groundwater formation in the Akhangaran river basin and around the Almalyk mining and metallurgical combine (AGMK), changes in groundwater levels at water intakes, precipitation, and evaporation in the study area. Comprehensive research methods, include the analysis of scientific and technical information on the geographical, hydrogeological, geomechanical and mineralogical compositions of the Almalyk industrial region, underground and surface waters, as well as the study of all valuable components by chemical, and X-ray structural methods, and atomic emission spectroscopy. Integration and point methods are used for measuring current velocity. Basic, detailed, abbreviated and graphical methods for measuring water flow are performed by electric meters. Experimental filtration studies are carried out and systems of observation wells are organized. Additionally water temperature is measured with thermocouples and water density, salt concentration, and water pH are measured using ionomers.

Key words: Groundwater, Akhangaran river basin, Almalyk mining and metallurgical combine (AMMC), industry, water intakes, groundwater level.

1 Relevance

The global demand for drinking water is growing day by day. Drinking water quality suitable for consumption is mainly found in groundwater. Groundwater is used as drinking, industrial, and irrigation water. In this regard, groundwater located in underground reservoirs of rivers between mountains is of incomparably great importance, and they serve as the main source of drinking water for urban and rural residents. In addition, the concentration of the population, the development of industry in urban and regional centres further increase the need for groundwater. The development of industrial horticulture, especially in drylands located in the foothills, increases the need for the use of groundwater for irrigation purposes. [1-8].

In recent years, population growth, urbanization, the rapid development of industry and its penetration into sparsely populated areas have often led to pollution of all water sources, including underground ones. Therefore, the protection of groundwater, its saving and
rational use, and maintaining its purity for technical and drinking purposes, is one of the most urgent problems of our time. [9-16]

The problem of the quality and quantity of water resources has become the main problem in most countries in the world. In particular, the territory of Uzbekistan is located in an arid zone, and the issues of saving water, especially the use of groundwater in the coming years, are one of the most pressing. [10]

The Akhangaran river basin (fig.1) is one of the industrialised regions of Uzbekistan, and the presence of the cities of Angren, Almalyk, and Akhangaran, as well as the Angren coal mine, the Angren Thermal Power Plant (TPP), and the Almalyk Mining (fig.2) and Metallurgical Combine (AMMC), once again emphasises the importance of studying groundwater reserves, water quality, and use of the Akhangaran river basin in the formation of groundwater. [3; 9; 11; 15; 17].

This study evaluates the surface and ground-waters of the Akhangaran River basin. The Akhangaran River is located between the Chatkal ridge and Kuramin ridge, with a height of 2710 m, and coordinates of 41°17′55″ and 70°37'13″. It has a length of 236 km, a basin area of 7710 km², and a water consumption of 22.8 m³/s, (by Turk village).

Fig. 1. 3D map at Akhangaran river basin.

Today, in the practice of most countries of the world, conducting scientific research aimed at studying changes in the groundwater regime is one of the main scientific areas in the field of physical geography. Violation of the groundwater regime is one of the problems of the first level in most countries. In many countries in the world, some scientific research is being carried out on water level management systems and their improvement. Due to the fact that the physiographic and hydrogeological conditions of each region on earth and the groundwater regime are different, it is important to conduct scientific research to identify, evaluate, and scientifically substantiate the factors affecting them. [6; 13; 14;]
2 Materials and methods

Comprehensive research methods include the analysis of scientific and technical information on the geographical and hydrogeological state of ground and surface waters of the Almalyk industrial region. Experimental studies have been carried out, and systems of observation wells have been organized. Analytical methods, experimental methods, and stationary observations during the operation of water intakes. The geobotanical method, which allows using plants to easily determine the occurrence of the aquifer; the method of determining the water level for wells that are located near the site; and the method of using test wells that show the presence and depth of groundwater. [4; 12; 22].

The purpose of the work performed is to monitor water resources and assess the state of the underground hydrosphere. The results of these studies will allow the determination of groundwater reserves and the rational use of water resources and will prevent the negative impact of anthropogenic factors on the level of groundwater.

3 Object of study

As a result of the survey of water intake areas, 24 reference points for monitoring the state of groundwater levels in the Akhangaran basin of the Tashkent region were identified. The following provides information on the most typical water intakes.

Karakhtai coastal (vacuum) water intake. The water intake consists of 13 production wells. It works in vacuum mode. Water withdrawal for the year amounted to 14,128,999 m$^3$. 5 reference points (observation wells)-1n, 2n, 3n, 1an, and 3an were identified on the territory of the water intake.

Karakhtai areal water intake. The water intake consists of 14 production wells. Water intake for the year amounted to 7,583,659 m$^3$. On the territory of the water intake, 2 reference points (observation wells) were identified - 28n, 328n.

Tashkent's water intake. The water intake consists of 26 production wells. Water intake for the year amounted to 26,785,192 m$^3$. 14 reference points (observation wells) were identified on the territory of the water intake-2a, 533n, 4a, 35r, 501n, 502n, 503n, 63, 530n, 531n, 532n, 11b, 528n, 527n.

Tash-Sartamgaly water intake. The water intake consists of 11 production wells. Water withdrawal for the year amounted to 9,090,781 m$^3$. On the territory of the water intake, 3 reference points (observation wells) were identified-512n, 578n, and 513n [3:19:20].

4 Results and discussions

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The average monthly fluctuations in the groundwater level, the monthly amounts of atmospheric precipitation, as well as the dependence of the groundwater level on the amount of precipitation and evaporation from the surface, are shown in fig. 3-4.

The Tash water intake has the largest number of observation wells (I section + II section = 14 wells), which means that the pattern of average monthly fluctuations in the groundwater level is the most characteristic.

Let's analyze the figures of average monthly fluctuations in the groundwater level for each water intake.

Fig. 3 shows in 2021 at the Tash water intake, in the period January-February, in general, the groundwater level decreased very slightly. Although the amplitude was only 0.85 m, the annual minimum level of groundwater was recorded in February. Water at 9.35 m. Since March, an intensive rise in the level of groundwater has begun. Its value in March was +0.95 m, in April +3.62 m and in the period May-June +1.50 m. That is, for four months, the groundwater level rose by 6.07 m.

In June, the maximum annual value of the groundwater level was noted, which amounted to 3.28 m in general for water intake.

Thus, the amplitude between the annual maximum and minimum groundwater levels was 6.07 m.

Fig. 2. Map of – potentiometric surface and groundwater depths of the Almalyk-Akhangaran mining and industrial region.
Fig. 3. The graph of Tash water intake average monthly dynamic fluctuation of underground water, monthly rainfall and evaporation indicator (2021 y.)
May months, the amount of precipitation, the total of which for the period amounted to 208.5 mm, or 39% of the total for the year. The later beginning of the flood, during the study period, is also evidenced by the beginning of the runoff in the channel of the Karakiyasay River, when the first measurement of the water flow was carried out on 03/19/2020, whereas in the previous year, the date of the first measurement fell on 03.04. until 06/02/2020. After the maximum average monthly value of the groundwater level was recorded in June (3.28 m), its decrease began. The fall in the groundwater level occurs rather smoothly during July-August, then sharply and intensively, until October. In July and August, the magnitude of the decrease in the level of groundwater was, respectively, -0.18 and -0.31 m. Then in September, at -2.57, during this period the river dried up, there was a level jump. In October, a runoff of water appeared in the river and the level rose by +1.37 m. In November, the groundwater level dropped only by 0.39 m and amounted to 5.35 m. The minimum value of the groundwater level in the second half of the year was noted, which amounted to 6.34 m in general for water intake (December). The amplitude between the annual maximum in February and the minimum in June was 6.07 m. All this is due to the main physical and geographical factors of the territory: The onset of the summer-autumn low water period; extremely low runoff in the channel of the Akhangaran River in the observation area in the period July-September (3-5 m/sec) and the absence of the latter during October and until November 20, hence, as a result, the practical absence of groundwater recharge by river waters. Here, during this period, the reverse process occurs—that is, when groundwater begins to drain under the channel space of the river, thereby lowering its level. Influence of climatic factors (precipitation, air temperature, evaporation). In the period July-November, the amount of precipitation amounted to 111.6 mm, and half of that fell in November, at 53.7 mm. And this is at high average monthly air temperatures (annual maximum in July +27.1°, August +27°, September +21.7°, October +13.6°, November +6°) and significant levels of evaporation (maximum in August 198.4 mm). In the second decade of September, there was a sharp drop in the groundwater level, especially at the first alignment of the Tash water intake, so well 2a - 2.85 m, well 533n - 3.27 m, well 4a - 3.07 m, well 35r - 2.76 m. During this period, the Akhangaran riverbed was dry. During the third decade of September, the groundwater level continued to fall here, but to a much lesser extent, and in October, the groundwater level began to rise to +2.71 m in well 2a, 533n - +3.49 m, 4a - 3.73 m, and 35r - 4.03 m. During this period, precipitation was observed and a runoff appeared in the bed of the Akhangaran River. At the second alignment during this period, a drop in groundwater levels was also observed, in well 528n to -1.64 m in the first decade, -1.55 m in the second, and -0.62 m in the third decade. From October to November, the levels continued to rise, and from November they began to rise, but not significantly. In 2021, over the entire area of the Tash water intake, for almost the entire year, groundwater levels were higher than in the previous one. The exception was the month of June, when, during the study period, the average monthly groundwater level was only 0.02 m lower than in the previous one. The greatest difference was noted in November at +3.95 m, the smallest in March at +0.06 m. When comparing data on fluctuations in groundwater levels in 2021 and 2020, the following should be noted: the peaks of the highest positions of groundwater levels fall in the month of June, and their values were: in 2021, 3.28 m, and in 2020, 3.26 m. It can also be noted that in 2021, the maximum is lower by 0.02 m than in the previous one. In the other months of the study year, the groundwater level is higher than the previous year. The amplitude is from +0.15 m to +3.95 m. For example, in January 2021 it is 8.50 m, and in 2020 it is 9.44 m; August...
In general, judging by surface runoff and annual precipitation and groundwater levels, 2021 turned out to be more watery. The amount of precipitation was more than in the previous year by 169.3 mm. The minimum groundwater level during the study period, as in the previous one, fell in the month of February, with values of 9.35 m and 9.88 m, respectively, and the difference, in relation to the year of the study, was 0.53 m; in 2021, in the area of the Tash water intake, throughout the year, groundwater levels were higher than in the previous one.

At the Tash-Sartamgaly water intake, regime observations of the groundwater level were carried out in three observation wells. The minimum level was noted in January at 3.79 m, and the maximum in May at 1.78 m, i.e., their amplitude was 2.01 m. From graph 2-3, it can be seen that after the maximum groundwater level in May, until August, the level dropped to 2.96 m, and the amplitude was 1.18 m. It should be noted that the volume of water supply from the Sharkhi hydroelectric complex to the Tanachi-Buka canal has decreased during this time period. The evaluation was carried out on 2 out of 3 observation wells located closest to the channel.

In August, the level rose to 2.05 m, and there was a slight decrease in the groundwater level, which in December amounted to 2.57 m.

Comparing the graph of groundwater level fluctuations in 2021 with the data of 2020, we can draw the following conclusions (fig. 4).
During the study year, during the period January-May, groundwater levels maintained a certain stability. The difference in their average monthly values between February and May was only 0.20 m. A somewhat different picture was observed in the previous year. Here, in February, there was a drop in the groundwater level by 0.20 m. Then, in March, a rise of 0.14 m. The total difference between January and March was 2.01 m, and last year it was 1.96 m, not significant. In the previous year, the minimum value of the groundwater level, in the context of the year, fell on January 3.71 m and in the year of the study, also on January 3.79 m. Further, after the peaks, the maximum position of the level begins its gradual decline to the minimum values of the groundwater level; in the previous year it was noted in December at -3.03 m and in the year of the study it was in November December at -2.57 m. The amplitude between the maximum level of groundwater and the minimum at the end of the year was: in the year of the study, 0.79 m and in the previous 1.46 m. The difference is 0.67 m.

The graph shows that the groundwater level fluctuated insignificantly throughout the year. The annual minimum groundwater level was 2.18 m in February, and the maximum level was in May and amounted to 1.32 m. The amplitude was 0.86 m. The measurements of the groundwater level determine the constant dynamic level.

In the Karakhtai Areal water intake, the maximum groundwater level was in May and amounted to 1.73 m. The minimum was observed in March at 3.21 m. Here the amplitude was 1.47 m in relation to the maximum in May precipitation.

When comparing the levels of groundwater in the studied and previous years, it should be noted that there is a very slight difference in their values.

Thus, the maximum difference at the coastal water intake was observed in February and amounted to 0.25 m in relation to the studied year, and at the area water intake in March, 0.47 m.

5 Conclusions and recommendations

The groundwater regime in the study area is formed under the influence of a number of physical and geographical factors, the most important of which are:

1. a) climatic - changes in meteorological factors (precipitation, air temperature, evaporation rate);
2. b) hydrological - changes during the year in the regime of surface runoff (river Akhangaran and its tributaries);
3. c) artificial - drainage (operation of water intakes) and watering (discharge of industrial waters, edge flooding, irrigation of agricultural lands).

Analyzing the graphs of average monthly fluctuations in the level of groundwater at the Tash, Tash-Sartamgalinsky, and Karakhtai water intakes in 2021, we can draw the following conclusions:

- the minimum level of groundwater occurs in January for the Tash-Sartamgaly water intake; in February for the Tash; in December for the Karakhtai coastal water intake; and in March for the Karakhtai areal water intake;
- the maximum position of the groundwater level was observed in May at the Karakhtai coastal water intake, Karakhtai areal and Tash-Sartamgaly, June at the Tash water intake;

Analyzing the state of groundwater levels in the Tash water intake in the autumn-winter period (October-December), it should be noted their sharp rise in October, which was especially pronounced at the first site. In relation to September, the groundwater level rose by 1.37 m, which is normal for water intake. In some wells, this value was up to 4.03 m (well 35r). The reasons for this behaviour of the groundwater level are outlined above.
A similar picture was observed in previous years. The exception was 2020. Here, the groundwater levels in October-December (8.82-7.12 m) had an amplitude in relation to September of 1.91 m.

The accumulated statistical material will allow us in the future to identify certain patterns, which, in turn, will make it possible to make fairly reliable forecasts of the behaviour of groundwater, which is necessary for its rational use.

In the area of location of the Tash, Tash-Sartamgalinsky, and Karakhtai industrial water intakes, throughout the reporting year, a practically stable qualitative composition of groundwater was maintained. In general, for water intakes, a significant increase in the contents of constituent components was not observed, and their fluctuations, at the extreme northern (well 4a) and southern (well 37) points, amounted to a minimum and maximum value, respectively: mineralization from 287 to 274 mg/l in spring and from 275 to 353 mg/l in autumn; total hardness is from 4.4 to 4.8 mg/l in spring and from 4.2 to 4.1 meq/l in autumn. It should be noted that in the year of the study, for comparison, as the southernmost point of sampling, well No. 37 of the Tashsko-Sartamgaly water intake was used and not well 36, as in the previous year.

Well 37 is located to the west of well 36, and chemical analysis revealed a better qualitative composition of the water sample in it than in the well 36. In previous years, when samples were taken mainly from wells 36, the similarity of their qualitative composition with that of samples from wells 32, and from the Urgazsay water intake, and all of them are practically in the same alignment. Apparently, a local deterioration in the quality of groundwater occurs here due to the inflow of fissure waters of a more unfavourable quality from the foothill zone of the Kuraminsky ridge, on which the Almalyk ore region is located.

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