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## **FORMATION AND DISTRIBUTION OF GROUNDWATER IN THE MIDDLE ZARAFSHAN REGION**

**Abstract.** The formation, distribution and hydrogeological characteristics of groundwater in the Middle Zarafshan region were studied. The geological structure, tectonic development and patterns of groundwater formation within different sedimentary deposits were analyzed. Atmospheric precipitation, infiltration of river and irrigation waters were identified as the main sources of groundwater recharge. The mineralization level, chemical composition and spatial variability of groundwater were evaluated. The obtained results are important for rational use of water resources and hydrogeological assessment of the region.

**Keywords.** Groundwater, Middle Zarafshan, hydrogeology, artesian basin, alluvial deposits, proluvial deposits, groundwater regime, mineralization, water resources.

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## **ФОРМИРОВАНИЕ И РАСПРЕДЕЛЕНИЕ ПОДЗЕМНЫХ ВОД В СРЕДНЕЗАРАФШАНСКОЙ ОБЛАСТИ**

**Аннотация.** В статье рассмотрены особенности формирования, распространения и гидрогеологические условия подземных вод Среднего Зарафшана. Проанализированы геологическое строение региона, тектоническое развитие и закономерности формирования подземных вод в различных отложениях. Установлено, что основными источниками питания подземных вод являются атмосферные осадки и инфильтрация поверхностных вод. Рассмотрены минерализация, химический состав и территориальные изменения подземных вод. Полученные результаты имеют важное значение для рационального использования водных ресурсов региона.

**Ключевые слова.** Подземные воды, Средний Зарафшан, гидрогеология, артезианский бассейн, аллювиальные отложения, грунтовые воды, минерализация, водные ресурсы.

**Introduction.** At present, the wise use of water resources and the assessment of their ecological condition is considered one of the global problems. In particular, in arid regions groundwater plays a vital role as the primary source of drinking water and irrigation. For this reason, studying the hydrogeological conditions of the Middle Zarafshan region is of pressing scientific and practical importance.

The formation of groundwater is linked to atmospheric precipitation, the condensation of atmospheric moisture in the fissures of rock and in the voids between soil and sand, and the widespread natural processes of seepage. At the same time, the infiltration of surface runoff into the ground also plays a major role in the formation of groundwater.

The Middle Zarafshan Basin is situated in the central part of the Zarafshan River basin and is a tectonic synclinal deposit in terms of its origin. The basin is bounded to the north by the relatively low-lying Gubdintog-Oktoq-Koratog range and to the south by the Chakilkalon-Koratepa-Zirabulok-Ziyovuddin range. The Zarafshan depression stretches for 160 km in a north-south direction, with an average width of 70 km. Its widest point lies on the Samarkand meridian. It narrows towards the west. Near the village of Hazar, the Kiziltepa and Oftobachi ridges converge, forming the 8–10 km-wide Hazar Corridor (Ali A., Quvodiq Y., Elmurod U., 2021).

The main part of the Middle Zarafshan basin consists of sedimentary rocks of the Paleogene and Neogene periods. Here, the marine basin that existed until the Neogene was transformed into land by the Alpine orogeny. By the Quaternary, alluvial and proluvial deposits formed under continental conditions had covered the Paleogene and Neogene strata. As a result of the Alpine orogeny, the Zarafshan River, which cut across the Zarafshan Basin that had become arid, deepened its channel and formed extensive alluvial terraces (Ali A., Quvodiq Y., Elmurod U., 2021).

The surface of the Zarafshan depression rises gradually from west to east and from the centre towards the north and south. The absolute elevation of the basin ranges from 350 m around the Pakhtachi fortress in the west, to 470 m at Kattakurgan, 680 m at Samarkand and over 1,000 m at Urgut in the east. In the Zarafshan Basin, besides alluvial and proluvial deposits accumulated during the Neogene and Quaternary periods, loess formations of considerable thickness are also widespread. For this region, as in the other mountain basins of Central Asia, activity of recent tectonic movements is characteristic. According to G.P. Gorshkov's (1949) seismic zonation scheme for Central Asia, the Middle Zarafshan basin falls within a 7-8 point seismic zone.

## LITERATURE REVIEW AND METHODS

During the research, methods of geographical analysis, hydrogeological comparison, historical-geological approach and cartographic analysis were used. To determine the geological structure of the area and the formation and distribution of groundwater, existing scientific literature, borehole data and hydrogeological monitoring results were analysed.

The hydrogeological conditions of the Middle Zarafshan Valley have been studied by many researchers. Initially, I.V. Mushketov, G.D. Romanovsky and others prepared the first generalised work on the geology and hydrogeology of the Middle Zarafshan Basin, compiled by A.M. Kulchitsky (Ҳикматов Ф.Ҳ., Ҳайдаров С.А., Ярашев ҚС. ва бошқалар, 2016; Eshkuvvatov B.B., Yarashev K.S., 2020). Studies of the basin's plains section for water supply purposes were carried out by P.I. Butov, S.F. Mashkovsev, V.A.Nikolaev conducted exploratory and experimental work to determine the filtration properties of the rock, groundwater levels, temperature, and variations in the water table (Ҳикматов Ф.Ҳ., Ҳайдаров С.А., Ярашев ҚС. ва бошқалар, 2016; Абдулкасимов А., Ярашев К.С., Мелиев Б.А., 2015).

## RESULTS AND DISCUSSION

Hydrogeologists distinguish the Zarafshan artesian basin in the Zarafshan Valley and delineate within it a separate Samarkand basin (Sultonxujayev et al., 1965). The Samarkand groundwater basin, from a geological standpoint, belongs to the Samarkand megasynclinal structure and extends from east to west via Panjakent, The Jumabozor and Kattakurgan folds occupy a large area, and in places the thickness of the Mesozoic strata reaches 2,000 metres. The Mesozoic deposits consist of Jurassic and Cretaceous strata. The Jurassic deposits comprise clay, siltstone, sandstone, gravel and conglomerate, with thicknesses in some places reaching up to 500 metres. Cretaceous and Paleogene deposits consist of conglomerates, gravels, sands, sandstones, siltstones, mudstones and limestones.

Neogene deposits are continental in origin, composed of conglomerates, gravels, sandstones and clays; their thickness reaches 1,000 m (Ali A., Quvodiq Y., Elmurod U., 2021).

Quaternary deposits are the most widespread and are classified according to their origin into alluvial, proluvial and deluvial types. They consist of gravel, pebble-limestone and sandy clays. These various deposits differ from one another in their permeability, water retention, water storage characteristics and chemical composition. Of these deposits, clay, fossiliferous sandstone and alluvial deposits are impermeable, and as a result groundwater accumulates beneath them on various scales.

In the Kattakurgan anticline, when the borehole drilled to the Cretaceous strata reached a depth of 569 metres, water was ejected to the surface from conglomerates composed of fine gravel, with a salinity of 1.2 g/l and a temperature of +45°C. The water is of the sulphate–chloride–sodium type with a flow rate of 1.1 l/s. Near the village of Ulus, at a depth of 142–165 m, water was ejected to the surface from a layer composed of Cretaceous-aged clay, sandstone, gravelite and conglomerate strata, situated beneath 109 m of Kaynaza deposits. The water is a sulphate-chloride, sodium-magnesium-calcium freshwater with a mineralisation level of approximately 1 g/l and a flow rate of 1.3 l/s (Ҳикматов Ф.Ҳ., Ҳайдаров С.А., Ярашев Қ.С. ва бошқалар, 2016; Ali A., Quvodiq Y., Elmurod U., 2021).

The drill-hole sections showed that, as one moves south, the Kaynazay deposit layer thins; at the foothills of the Zirabulok and Ziyovudin mountains, Cretaceous deposits outcrop at the surface. These areas are considered the saturation zone for the Cretaceous deposits. The spring waters emerging from the Cretaceous deposits are fresh in the mountain and foothill valleys, with a mineralisation level not exceeding 1.0 g/l and, in many cases, amounting to 0.6 g/l.

In the boreholes drilled around the villages of Ulus and Nagornaya, the salinity of the water in the Jurassic deposits underlying the Cretaceous was found to be quite high, characteristic of the Neogene and Pliocene high-pressure

groundwater. They contain water-bearing horizons of sands and gravels, with depths ranging from 90 to 412 metres; the water yield is substantial, at 10 metres per second and above; the water quality is good to satisfactory or slightly saline (Ҳикматов Ф.Ҳ., Ҳайдаров С.А., Ярашев Қ.С. ва бошқалар, 2016; Ali A., Quvodiq Y., Elmurod U., 2021).

It is difficult to state definitively the law governing the occurrence of pressurised waters in the Tertiary deposits of the Samarkand artesian basin; these deposits outcrop at the surface in mountain and sub-mountain zones. One can agree with the view that, at the points where these Tertiary deposits outcrop, atmospheric precipitation infiltrates and generates waters characteristic of the Tertiary. If the Tertiary deposits are overlain by porous, water-permeable Quaternary deposits, then in such cases water passes through these porous, through the permeable Tertiary strata, accumulating on the Tertiary beds (Sultonxujayev et al., 1965).

The pressurised, sometimes self-flowing waters of the Quaternary period lie at depths of 50–60 metres, and sometimes at 200 metres. These waters are mainly fresh, though occasionally slightly saline, and are used primarily as drinking water and partly for irrigation. The degree of mineralisation of the Quaternary pressurised groundwater also varies across the Zarafshan Valley from east to west, that is, it increases. At a depth of 335 metres in a drilled borehole near the town of Bulungur, pressurised water was found among the gravels, and the water rose to 45.5 metres. The mineralisation is 0.2 g/l, and the water is pure, hydrocarbonate-calcium in composition. Near Samarkand, pressurised waters were found at depths of 11 m, 47 m and 66 m within the gravelly sandstone deposits; they contain 0.9 g/l of minerals and consist of hydrocarbonate–sulphate calcium salts. Towards the west, the water's mineralisation increases. For example, near the town of Koriona, at a depth of 4.6 metres, the water between the gravel has a mineralisation of 1.1 g/l and is of the sulphate–bicarbonate–magnesium type. The water table rises to 4.6

metres (Ҳикматов Ф.Ҳ., Ҳайдаров С.А., Ярашев Қ.С. ва бошқалар, 2016; Ali A., Quvodiq Y., Elmurod U., 2021).

Samarkand Province, which occupies the greater part of the Middle Zarafshan Basin, has a terrain that is over 50% mountainous plains, the alluvial deposits consist of angular stones of varying sizes, and as one moves away from the mountains their composition changes, giving way to fine sandy clays towards the Zarafshan River. This situation affects the zone and quality of groundwater. The sources of groundwater in the proluvial deposits are the mountains.

According to A.N. Sulstonxujayeva et al. (1965), the waters in the proluvial deposits also serve as a source, being water that rises up through fractures in the rocks laid down beneath these deposits during the Quaternary. In the nearby foothills, the waters in the proluvial deposits reach depths of 30–40 metres, sometimes 60–70 metres. As one moves away from the mountains towards the river, the water approaches much closer to the surface, for example, near the Juma and Zirabulak mountains their depth is 20 m, and close to the river it decreases to 2–3 m, and in places near the surface they come very close to it, forming marshes and swamps (Eshkuvvatov B.B., Yarashev K.S., 2020; Ali A., Quvodiq Y., Elmurod U., 2021).

The mineralisation level of groundwater in the proluvial deposits is not high. For example, near the town of Juma it is 1–2 g/l. The water is hydrocarbonate–sulphate–magnesian and sulphate–bicarbonate–magnesian. Towards the west, on the foothill plains, the water's mineralisation increases, reaching 5.0 g/l in the village of Nagorniyy, the town of Zirabulak and the village of Malik. The water is composed of sulphate–chlorite–sodium salts.

The groundwater in the alluvial deposits of the Zarafshan Valley is rich and moderately mineralised. They are fed by the river, canals, ditches and irrigation waters. The gravel-sand mixed deposits are highly permeable, so the water in them is constantly being renewed. The water depth ranges from 1.0 to 4.0 metres, decreasing towards the river, and on the riverbanks it approaches the surface,

forming marshes. When the river is in flood, groundwater spreads into the surrounding land, raising the water table, and in the winter months, when the river's flow diminishes, the groundwater level falls (Yarashev Q.S., Eshquvvatov B.B., Valiyeva Sh.I., 2020; Eshkuvvatov B.B., Yarashev K.S., 2020).

In the eastern part of the river valley, the mineralisation level of the groundwater does not differ from that of the river water, amounting to 0.3–0.5 g/l. The water composition consists of hydrocarbonate–magnesium salts. Water of this composition and quantity persists up to near the city of Khatirchi. Thereafter, water of the same composition continues westwards along the riverbank in the form of a narrow spring. This includes the river bend and the lower parts of the first terrace's riverbed. Due to the considerable height of the second terrace, water exchange with the river becomes much more difficult. In the western parts of the valley, the water salinity rises to 5–10 g/l, and soil salinisation intensifies.

In Samarkand province, the use of groundwater is quite well organised. In the region, over 80% of villages are supplied with artesian water, 10% of the population use mountain spring waters, and 10% use groundwater (wells). Artesian water is also widely used in the cities. For example, in the city of Samarkand, artesian well water is used to irrigate fountains, swimming pools, flowerbeds and green spaces. In addition, some enterprises, organisations, institutions and even families with private swimming pools also use artesian water (Yarashev K.S., Ulugmurodov E.B., Norboyeva M.O., 2022).

The degree of mineralisation of the water is clearly evident when compared from east to west across the Zarafshan Valley. At the same time, at water hardness up to 0.6 mg/l, hydrocarbonates predominate among the anions, and calcium is abundant among the cations. As the water hardness exceeds 1.0 mg/l, sulphates replace hydrocarbonates as the main anions. At the same time, in many cases the anions exhibit a high magnesium content. The increase in calcium and magnesium leads to an increase in water hardness. The water should primarily contain sodium as the cation. This is a characteristic feature of many regions of our republic

(Yarashev Q.S., Eshquvvatov B.B., Valiyeva Sh.I., 2020; Yarashev K.S., Ulugmurodov E.B., Norboyeva M.O., 2022). In the Zarafshan Valley, A.N. Sultonxujayev and others (1965) explain the appearance of magnesium instead of sodium among the cations by the abundance of rich limestones in this region and their weathering.

In the Zarafshan artesian basin, groundwater, like surface water, flows from east to west. However, depending on the geological structure of the site and its metamorphic erosional state, in some cases artesian waters become trapped between strata, forming local water reservoirs. In the Zarafshan artesian basins, the waters vary in chemical composition and salt content. Here, one can encounter freshwater of the Quaternary period alongside saline waters in Jurassic deposits.

In Quaternary deposits the waters are freshwater, although in some cases slightly brackish waters are also encountered. These waters are used by the population for drinking and irrigation. The water resources of Neogene deposits have been well studied. However, analysis of the available data shows that among Neogene deposits there are many low-salinity, naturally flowing waters. The waters in the Paleogene chalk deposits consist of low-mineralised waters. However, as the water moves away from its source of formation and becomes increasingly saturated in the aquifer, its salinity increases, reaching very saline levels.

The water resources of the Jurassic deposits have not been studied. According to data from boreholes drilled in the Kashkadarya Basin, the artesian waters are very saline, even brine-like, and rich in iodine, bromine and lithium. Hydrologists Barisov and Mirzayev record that the Zarafshan Basin has three types of groundwater: 1) in fissures and fractures; 2) inter-layer; 3) groundwater.

The waters in the fissures and fractures of the rocks are encountered in Paleozoic mountain formations. The mountains formed from Paleozoic rocks are those surrounding the Zarafshan Valley. In these mountains, the Paleozoic limestones, shales, sandstones and volcanic rocks are characterised by numerous fissures and a high solubility in water. For this reason, karst springs are numerous

in limestone areas, with a flow rate of up to 70–80 l/s. It should be emphasised that because limestone and dolomite are highly soluble in water, their fissures are filled with water and, once they lie above impermeable strata, emerge at the surface as springs. The waters between the strata occur in Cretaceous, Paleogene and Neogene deposits, which crop out on the mountain slopes and plateaus. These deposits consist of sands and sandstones, conglomerate, clays and marls, and limestones (Yarashev Q.S., Eshquvvatov B.B., Valiyeva Sh.I., 2020).

Groundwater is widespread in the Zarafshan Valley. The porosity of the alluvial-proluvial deposits allows atmospheric precipitation to pass rapidly through rivers, streams, canals and watercourses, replenishing the groundwater reserves. They emerge locally as springs and form surface runoff. For example, Qarasuv (Siyob) is one such watercourse. In particular, large volumes of water from the riverbed and floodplain are lost to groundwater recharge. For example, according to X. Sidiqov (1989), between the Dupuli station and the Oq-Qoradaryo dam, 17.4 m<sup>3</sup>/s of water is lost to seepage into the riverbed gravel (ҲИКМАТОВ Ф.Ҳ., Ҳайдаров С.А., Ярашев Қ.С. ва бошқалар, 2016; Ярашев Қ.С., Улуғмуродов Э.Б., 2022).

According to N.M. Reshetkina (1975), the total groundwater volume in the basin from the Ravotkhoja node to the Lower Zarafshan is estimated at 3.7 billion cubic metres. Most of this originates from water infiltrating into irrigated lands. In the Zarafshan artesian basin, the amount of groundwater formed naturally amounts to 135.4 m<sup>3</sup>/s. Of this, 51.9 m<sup>3</sup>/s is generated between the Ravotkhoja and Oq-Qoradaryo water reservoirs. This is the water reserve fed by the drinking-water intake.

At the upper part of the Zarafshan fan, groundwater formed by filtration moves in a east-to-west direction, and as it approaches the toe of the fan, it approaches the surface, after passing through the village of Tokay, it begins to emerge at the surface across a broad expanse and forms the Karasuv tributaries. The intensive seepage of groundwater to the surface continues up to the middle

reaches of the Okdaryo and Koradaryo tributaries. The large-scale seepage of groundwater occurs during the river's low-flow period and contributes to the increase in its water volume during the mezen period (Shuls, Mashrapov, 1969; (Ҳикматов Ф.Ҳ., Ҳайдаров С.А., Ярашев Қ.С. ва бошқалар, 2016; Yarashev K.S., Ulugmurodov E.B., 2022).

Such a hydrogeological regime is also characteristic of the western part of the Zarafshan Basin. This is because the Zarafshan Basin is formed by two independent tectonic basins – the Jumabozor and Kattakurgan basins – which are separated from one another by a tectonic uplift. This uplift acts as a barrier to the valley-parallel flow of groundwater, allowing it to seep to the surface.

## CONCLUSION

The results obtained serve as a scientific basis for the effective use of groundwater resources, their protection and the assessment of the region's hydro-ecological condition in the Middle Zarafshan area. Accordingly, the hydrogeological regime of the Samarkand oasis is extremely diverse. Here, the groundwater table's proximity to or distance from the ground surface and its distribution pattern depend on several factors. The lithological composition of the parent rocks, the genetic type of the relief, the slope of the land surface, and so on, play a leading role in the geographical distribution of groundwater and the location of the groundwater table. Therefore, in the Zarafshan Basin, including the Samarkand oasis, the depth to the groundwater table varies from 15–20 m on the foothills to 1–2 m in the river valley (Ярашев Қ.С., Улуғмуродов Э.Б., 2022; Yarashev K.S., Ulugmurodov E.B., 2022).

The groundwater is freshwater and fit for consumption. Its mineralisation increases along the flow direction from 0.1 g/l to 1.0 g/l. On the foothill proluvial plains and the upper terrace of the riverbeds, favourable conditions for groundwater movement are created. Consequently, in these areas the groundwater lies at considerable depth. In the sections of the region's Zarafshon River terraces

and on some lowlands, including Toylok, In the areas of the Zarafshan River terraces and some lowlands, including the districts of Toylok, Jomboy and Payarik, groundwater lies very close to the surface, over-moistening the soil cover and activating the process of marshland formation.

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