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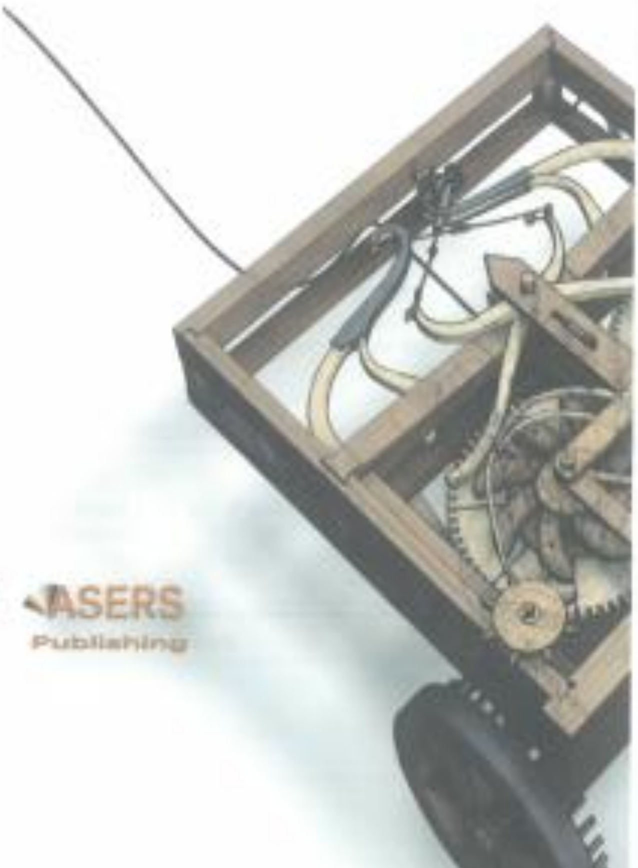

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Analysis of Groundwater Resources in the Kyrgyz Republic

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Abstract:

The relevance of this article is beyond doubt since the groundwater resources of the Kyrgyz Republic are very important for providing the population with drinking water. The article provides an analysis of groundwater reserves in the Kyrgyz Republic. The volumes and conditions of groundwater are given. On the territory of Kyrgyz Republic over its entire area, natural underground "lakes" are widespread. Determined the depth of groundwater reserves. Groundwater distribution flows were described. Groundwater contamination by nitrates and nitrites has been identified. Unsystematic creation of frequent water intakes, lack of monitoring of their operation can lead to aggravation of the situation with groundwater, lead to increased pollution and depletion processes. Since this topic has previously been little studied, the novelty of this article lies in the fact that the authors analyzed the causes of pollution of groundwater and offered their own ways to solve this problem.

Keywords: water resources; pollution; monitoring; operation; water intake; depletion.

JEL Classification: Q25; Q26; Q28.

Introduction

A distinctive feature of the natural conditions of Kyrgyz Republic, as compared to other Central Asian states (CA), is that the river flow of watercourses is fully formed within its territory. Note also that the river flow falls into the category of renewable water resources and is of exceptional importance both for the maintenance of human life and for the preservation of the natural environment. In addition to renewable water resources, there are also static categories (species) in nature that have a renewal period of centuries and even millennia. The total water resources of Kyrgyzstan (renewable and static), calculated in (Oruzbaeva 1982), are listed in Table 1.

The data in Table 1 show that the share of river water accounts for no more than 9% of the total water resources of the territory in question. Most of all freshwater resources are concentrated in glaciers – 88%. Despite the relatively small contribution of river flow, its importance is enormous, especially in the use of hydropower resources and the water supply of agricultural sectors. River flow is directly involved in the formation of disposable water resources. Kyrgyzstan uses 20-25% of the available water reserves, the rest of the flow goes to the neighboring countries: Kazakhstan, China, Tajikistan, Uzbekistan.

Table 1. Total water resources of Kyrgyzstan, km^3/year

Category	Shared water resources	%
River flow	48,7*	8,7
Glacier water reserves	494,7	88,2
Water reserves in lakes	6,2**	1,1
Groundwater	11,0	2,0
Total	560,6	100

Note: * – without taking into account the rivers of underground power supply, such as "Karasu", whose flow varies slightly from year to year and totals 1.91 km^3/year; ** – without oz. Issyk-Kul.

As for the underground waters of Kyrgyzstan, at the present time they have not received due assessment and attention, as the most important strategic resource, no less important than oil and gold (Oruzbaeva 1982; Borodavchenko 1988; Abdurasulov *et al.* 1990; Kolesnik 1970; Azykova 1980). This is explained by the fact that both government officials and the general public do not have a sufficiently accurate understanding of groundwater and the problems associated with them. The importance of this type of resources is evidenced by the fact that in the past the assessment of groundwater reserves passed through the State Commission on Mineral Reserves of the USSR, at that time the Kyrgyz Hydrogeological Expedition was created, performing even today the main works on the study of groundwater status. At present, the financial support of the expedition is not enough to fully control the quality and quantity of groundwater, the regime of their rational use (Pezzini *et al.* 2016; Ramirez and Wolff 2017; Ponçano 2017; Seitkaziev *et al.* 2018; Rosa *et al.* 2018).

To a certain extent, this situation is explained by the fact that groundwaters by the total volume of the republic (654 km^3 in the 200-300-meter thick quaternary aquifer complex and renewable resources – 380 m^3/s) are inferior to the surface water resources concentrated in rivers, lakes, reservoirs. But groundwater has advantages that fully compensate for the relatively small volume. This is, first of all, the almost universal distribution within the intermontane valleys, high quality and independence from seasonal climate changes and the accompanying phenomena complicating the intake of surface water in the form of floods, mudflows. In addition, surface water, in contrast to groundwater, is easily subject to pollution.

Of course, the capital costs of obtaining groundwater are large enough, but with proper maintenance of wells, pumping equipment, we get a stable source of quality water, as close as possible to the consumer. The latter is associated with the main problem of groundwater pollution, since, as a rule, groundwater intake is located in the territory of settlements and all types of polluted solutions formed on their territory, to some extent, seep into the ground, reach the level of groundwater and pollute their (Shnitnikov 1980; Umurzakov and Vinnik 1975; Kadyrov 1986).

1. Characteristic of the Formed Groundwater

Groundwater is of great importance for the water supply of settlements, irrigation of agricultural land, and satisfaction of vital, industrial and other needs. The republic has mineral waters of all types and varieties. They are widely used for medicinal purposes and for drinking. Groundwater in the territory of Kyrgyzstan is used for various types of water supply, irrigation of land, as well as for balneological purposes. With the increase in the practical use of groundwater, the scale of conducting numerous hydrogeological studies also increased. The formation of groundwater in Kyrgyzstan is determined by its location in the territory of the mountain-folded areas Tenir-Too and Pamir-Alai. The peculiarities of the hydrogeological conditions and the groundwater resources of the republic are closely connected with geological and structural factors, relief and climate, as well as with the influence of human engineering activity.

In Kyrgyzstan, 3 main structural and hydrogeological floors are insulated: the upper one, which includes, respectively, pore groundwater in loose Quaternary sediments; medium – predominantly porous-fissure waters in semi-rock Neogene-Paleogene and Mesozoic rocks; lower – fissure, less often – fissure-vein and fissure-karst waters in Paleozoic and Proterozoic rocky formations. By combining these floors in the newest structural forms in the modern relief, 2 main hydrogeological structures are distinguished – hydrogeological massifs and artesian basins. They are most clearly manifested features of the formation and accumulation in the depths of the groundwater, their territorial distribution and internal redistribution along the path of movement.

Hydrogeological massifs are protrusions on the surface of the lower structural-hydrogeological floor, confined to folded-block elevations – mountain ridges, where fractured groundwater (unconfined) waters circulate in separate zones in the weathering zone at depths of several tens to 150-200. The structural and geological conditions within the republic distinguish the following types of hydrogeological massifs: composed mainly of igneous rocks (Kyunguysky, Teskeysky Ala-Too, Suusamyr ranges *et al.*), composed mainly of metamorphic rocks (Talas, Zhetimbel ridges *et al.*), formed by terrigenous, carbonate and volcanogenic rocks (At-Bashynsky, Kyrgyz, Kakshaal, Alai, Turkestan ridges *et al.*), built, and Turkestan ridges *et al.* rocks (Fergana Range). Hydrogeological massifs have a deeply dissected relief, large slopes of the slopes of the thalwegs, so the precipitation falling here is only slightly used to recharge groundwater, and for the most part they flow into the river flow. In view of this, groundwater reserves, both natural and operational, are relatively small here.

Artesian basins are groundwater reservoirs confined to complex folded-block depressions – intermountain depressions, where the upper and middle structural-hydrogeological floors, especially the upper ones, which have significant freshwater resources most accessible for practical use, are of primary importance. In Kyrgyzstan, there are several dozen basins of different levels with different conditions of accumulation of the cover and with different degrees of flow openness. Pools of sustained subsidence have the most complete section of Paleogene-Neogene and Quaternary sediments. Power cover 4-5 km. The power of only Quaternary accumulations is more than 300 tons. Such a cover structure creates favorable opportunities for the formation of groundwater resources. These are the Chuy, Talas, Ysyk-Kelsky, At-Bashynsky, Karavan-Kyokzharsky, Nookatsky, Alay, Fergana, Orto-Alysh pools.

Pools of unstable subsidence have a shortened section of Paleogene-Neogene accumulations, not continuous distribution of Quaternary formations, with a power rarely reaching 100 tons. These circumstances determined limited favorable opportunities for the formation of groundwater resources in such basins. These include the Alabuga-Naryn, Suusamyr, Jumgal, Toguz-Toros, Toktogul, Chon-Kemin, Chatkal, Chatyr-Kulsky, Ak-Sai pools. Inversion basins have a shortened section of Paleogene-Neogene sediments, the thickness of Quaternary sediments in them rarely reaches 50 m. Such a structure causes unfavorable possibilities for the formation of groundwater resources. The pools of this type include Son-Kelsky, Arpinsky, Kazhysaysky, Ara-Bel – Kum-Tersky, Verkhne-Narynsky, Sary-Zhazsky, Tleksky, Oktorkoysky, Isfara-Isfaninsky.

In total, about 50 artesian basins are allocated on the territory of Kyrgyzstan, of which about 30 are large and medium. As a rule, they have a three-storey structure and are divided into external, mainly Mesozoic-Cenozoic, which during the newest stage developed against the background of folded-block subsidence, and Internal-Cenozoic, which in the Quaternary period underwent a process of elevation together with hydrogeological massifs. The greatest resources are concentrated in the external artesian basins: Chui, Ysyk-Kelsky, Talas, Fergana (within the borders of the republic), etc. In the internal basins they are in most cases much less: Alabuga-Naryn, Toguz-Toros, Arpinsky, At-Bashynsky, Kochkorsky, Jumgal *et al.*

The total value of the natural resources of fresh groundwater of the republic is 330 m^3/s. In addition, in the thickness of Quaternary water-bearing rocks there are about 650 km^3 of static (capacitive) groundwater reserves, of which 300 km^3 are associated with the Chui artesian basin. The percentage of exploited reserves in different fields varies in different ways. The total operational water intake of groundwater is 5.2 million m^3/day, of which 2.0 is for household and drinking consumption, 2.3 for irrigation, 0.8 for industrial and technical consumption, 0.1 for irrigation of pastures (Altaliev *et al.* 2005). According to the anomalous composition and temperature, a large group of thermomineral waters stands out among the groundwater of Kyrgyzstan, which are suitable for use as therapeutic, energy or industrial. The total number of areas of occurrence and deposits of such waters in the republic is close to 150.

Also within all the plains of Kyrgyzstan, natural underground "lakes" are found throughout their area, mainly with clean fresh water. More precisely, groundwater reservoirs represent a thickness of about 300 meters of detrital rocks (gravel, sand, clay interlayers) saturated with water (quaternary aquiferous complex). The depth to the level of groundwater (from the surface of the earth to the surface of complete saturation of the breed "sponge") varies in different parts of the valleys, as a rule, it is large in the foothills. For example, near the foothills of the Chui depression, to the south of Bishkek, the depth to the water is within 150-200 meters, in the central part of the city – 30-50 meters, in the northern part – within a few meters, and in some places, in the hollows, underground water comes to the surface in the form of springs. Thus, the entire Chui depression represents a bowl, the bottom and sides of which are formed by rocky rocks, filled with loose rocks – pebbles, sand, clay, saturated with water.

It should be noted that the maximum thickness of the layer of detrital rocks saturated with underground water in the Chui depression is about 5000 meters in the southern part and decreases to the north to the first tens of meters in the valley of the Chu River. The above-mentioned layer with a thickness of 300 meters is only the uppermost, most loose and most water-rich layer from which groundwater is mainly obtained. At greater depths – up to 1000 meters – fresh groundwater is also contained, but with increasing depth the temperature of groundwater rises by 30°C for every 100 meters of depth due to the internal heat of the Earth. Therefore, at a depth of 1,500 meters or more, the groundwater is heated to a temperature of 50 degrees or more; they are called thermal, and in the case of the presence of elevated concentrations of soluble salts in the rocks, the terminal ones are mineral. In addition, with increasing depth, compaction of rocks increases, fragments are cemented by carbonates and silicates (natural cement), for example, sand becomes sandstone, therefore, porosity, and hence water saturation, decrease. Such a situation with some variations is typical for all large depressions of Kyrgyzstan.

Inside the earth, underground water enters from the surface of the earth, seeping from rivers, canals, and other bodies of water. Basically, it occurs in the foothills of the depressions, where the rivers flow out of the mountain gorges to the plains. In an underground reservoir, water flows slowly, at speeds from the first meters to fractions of a meter per year, between debris from the feed area, where the groundwater level is higher to the discharge area at the lowest part of the basin; in the Chui depression, this current occurs from south to north to the valley of the Chu River, in the Issyk-Kul depression all underground water is discharged into Issyk-Kul Lake, including in the form of underwater springs. The water from the rivers, being filtered through the strata of rocks, is purified, therefore, as a rule, in natural conditions the groundwater is clean (Petrov and Movchan 2017). Exceptions can only be cases where the rocks through which water is filtered, penetrating from the surface of the earth, or flowing under the ground, contain various soluble minerals and salts, this is the way natural pollution of water with chlorine, sulfate, fluorine occurs.

The flow of groundwater flows under any settlement and all the solutions that form on its territory can leak to the level of groundwater and contaminate them, mainly leaks from sewers, septic tanks and other sources (Shnitnikov 1980; Umurzakov and Vinnik 1975; Kadyrov 1986). As a rule, pollution is detected by the appearance of elevated concentrations of nitrates in underground water due to domestic wastewaters, as well as other elements associated with industrial activity – chromium *et al.* In the republic as a whole, within any settlement, the groundwater is polluted to one degree or another; the larger the settlement, the more enterprises that produce polluted runoff within it, the greater the area of foci of pollution and the concentration of pollutants. Filtration from fields under irrigation due to dilution of fertilizers, pesticides contributes to the pollution of groundwater, especially in conditions of shallow groundwater levels within the first meters.

2. Problems of Usage the Groundwater

Groundwater has almost ubiquitous distribution within the intermontane valleys, is characterized by high quality and is independent of seasonal climate change and the accompanying phenomena in the form of floods and mudflows, which complicate the intake of surface water. Capital costs for the extraction of groundwater are large enough, but with proper maintenance of wells and pumping equipment – it is a stable source of quality water, as close as possible to consumption.

The capacity of the exploited aquifers in different hydrogeological zones varies from 20 to 500 m. Explored by industrial categories, the operational reserves of fresh groundwater with continuous water withdrawal from 44 fields are 188 m^3/s (Gorelick and Zheng 2015; Milan *et al.* 2018). All deposits of fresh groundwater are used for drinking, household, industrial and technical (irrigation) needs. Volumes of natural reserves of underground flow pools are shown in Table 2. The dynamics of fresh groundwater abstraction shows that in the early 1990s in some years the water intake reached 1.1 km^3 per year, since 1992 it has decreased from 900 to 300 million m^3 and in recent years amounts to 299-324 million m^3. About 85% of water supply systems in Kyrgyzstan use groundwater. The use of groundwater reserves is 20-30%. The greatest degree of use of groundwater deposits in the capital and economically developed regions of the republic.

Table 2. The main basins of underground flow of Kyrgyzstan

Basins of underground flow	Natural reserves, km^3	Basins of underground flow	Natural reserves, km^3
Chuyskiy	300	Ak-Sayskiy	50
Orto-Alyshskiy	1	Chatyr-Kelskiy	15
Talasskiy	75	Arpinskiy	9
Yssyk-Kelskiy	58	Sary-Zhazskiy	1
Alabuga-Narynskiy	13	Ara-Belskiy	3
Susamyrskiy	16	Kara-Bulakskiy	1
Kochkorskiy	1	Ravatskiy	3
Zhumgalskiy	1	Batkenskiy	1
Ketmen-Tebenskiy	23	Taldelskiy	3
Son-Kelskiy	5	Byppgundinskiy i Aktorpokskiy	9
Toguz-Toroskiy	10		
At-Bashynskiy	20	Osh-Kara-Suuskiy	8
Kara-Kuzhurskiy	2	Kurshabskiy	15

Currently, insufficient funding for the operation and maintenance of water wells and the water supply network leads to the abandonment of the use of groundwater sources and a focus on the collection of less safe water from rivers and wells. Significantly reduced groundwater use for agricultural water supply. The decrease in the use of groundwater for irrigation with the use of drip irrigation contributes to the expansion of the areas of submerged and saline lands.

3. Causes of Groundwater Pollution and Its Solutions

In Kyrgyzstan, out of the total number of surveyed water bodies, the third part of rivers is classified as "dirty" and "very dirty". One of the factors for increasing the concentration of pollution is the deterioration of the existing treatment plant and the continuing discharge of untreated sewage into water bodies. The main pollutants enter water bodies with waste waters of enterprises of the machine-building industry and non-ferrous metallurgy. Water pollution in all river basins, exacerbated by inappropriate use, leads to environmental degradation and drying up of lake and river ecosystems.

The main reasons for the deterioration of water quality and depletion of reserves in the region are:

- salinity and hardness of water, as a consequence of the use of water for irrigation of land;
- discharge of untreated industrial and household waste into the zone of formation of surface and groundwater lenses;
- migration of nitrogen and phosphorus fertilizers, ballast elements, heavy metals;
- trace elements, pesticides in the zone of formation of surface and groundwater;
- non-compliance with the filtration requirements of industrial waste accumulation facilities;
- uneconomical use of water in irrigation and the use of water for technological needs;
- the lack of effective economic mechanisms to stimulate water conservation and metering of water consumption.

There are more than 90 graves containing uranium and toxic substances in the territory of the Kyrgyz Republic – a legacy left by the military industry and industries related to the military production of the USSR. This situation is further complicated by the fact that many burial sites are located in active seismic areas, mudflow areas, areas prone to flooding and high groundwater levels, as well as near river banks that form the basis of the vast Central Asian basin (Biancardi and Maddalena 2018; Kifanyi et al. 2019).

Solutions:

- Monitoring of radiation background;
- Carrying out rehabilitation works at tailing dumps;
- Recycling / recycling;
- Research and development work on the disposal and recycling of solid waste;
- Ensuring state monitoring of groundwater in transboundary areas.

Also, to prevent contamination of drinking groundwater, their zoning is necessary according to the degree of protection. Analysis of the structural features of the Quaternary sediments, their filtration properties and vertical hydrodynamics made it possible to regionalize the underground flow basins of Kyrgyzstan according to the degree of protection of groundwater from pollution (Figure 1).

Figure 1. Schematic map of the protection of groundwater basins in Kyrgyzstan

Note: 1 – unprotected; 2 – poorly protected; 3 – conditionally protected; 4 – transitional parts of the pools; 5 – internal parts of the pools; 6 – external parts of the pools

The results of the mapping show that groundwater of the Quaternary age is not protected from pollution in 10% of the distribution area, conditionally protected – by 3%, poorly protected – in 87% of the distribution area. A subsequent assessment of the protection of groundwater within specific basins will allow the formulation of basic principles for the sustainable use of water resources. Differentiation of the territory according to the degree of protection of groundwater from pollution will make it possible to formulate basic solutions for the protection of groundwater from depletion and pollution and to propose a number of preventive measures for specific territories. Zoning the protection of groundwater basins also plays a key role in setting priorities for water quality monitoring, environmental auditing of industrial enterprises, identifying possible activities at an acceptable level of risk of pollution for groundwater and pollution control within agricultural production.

Conclusions

The current state of groundwater in Kyrgyzstan as a whole during 2001, the beginning of 2010, did not undergo a significant change in comparison with the period 1998-1999. It can be stated unequivocally that no changes have taken place for the better, since the main negative factors continue to act. Despite the fact that the load on groundwater, both in pollution and in consumption, has decreased due to a decrease in production, however, in modern conditions, it is necessary to pay attention to the state control over the drilling of new water wells, the technology of their equipment and operation mode. Unsystematic creation of frequent water intakes, lack of monitoring of their operation can lead to aggravation of the situation with groundwater, lead to increased pollution and depletion processes.

The most important strategic resource of fresh drinking water should be under state control. This is especially relevant in connection with the climate tendency to desiccation and desertification in the Central Asian region, which is vividly confirmed by the degradation of the Tien Shan glaciers. Taking into account this trend, it is necessary to carry out monitoring of the quality and reserves of groundwater under the state-wide scale and with appropriate funding, as well as measures to create protected areas within which a strict regime of protection of groundwater from pollution and depletion will operate. These waters will serve as strategic reserves with possible, in the near future, adverse climatic changes.

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