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Organizational, Economic and Regulatory Aspects of Groundwater Resources Extraction by Individuals (Case of the Russian Federation)

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Abstract: Fresh groundwater, as an essential component of global water resources and a special type of mineral wealth, has a whole set of features that affect social infrastructure, the economy and the environmental well-being of the population. At the same time, groundwater is vulnerable and limited despite its replenishable nature and vast reserves. Recently, in some countries, the practice of extracting groundwater resources by private individuals on their territory has been actively spreading, but not in all states. This is considered acceptable and is enshrined in national regulations. Uncontrolled exploitation of aquifers by small water users can affect the safety of ecosystems and the depletion of drinking groundwater reserves. In this regard, the state policy and system for regulating access to groundwater resources for all subsoil users should be based on a well-thought-out concept. This article is devoted to the organizational, economic, and regulatory issues of groundwater extraction by individuals for their own needs in the Russian Federation. A comparative analysis of the state approach to groundwater extraction by private individuals in other states (mainly in the example of Germany and China) is made. The latest trends in legislation in this area are analyzed, shortcomings in the system of state regulation of groundwater use are identified, and mechanisms for legalizing the activities of individual water users are proposed. Global groundwater regulation should be based on rationality, control, safety, protection, sustainability, and future generations' care.

Keywords: groundwater; private person; individual subsoil user; domestic water supply; water well; aquifer; state regulation; GOST

Citation: Golovina, E.; Khloponina, V.; Tsiglianu, P.; Zhu, R. Organizational, Economic and Regulatory Aspects of Groundwater Resources Extraction by Individuals (Case of the Russian Federation). *Resources* **2023**, *12*, 89. https://doi.org/10.3390/resources12080089

Academic Editor: Jian Cao

Received: 5 May 2023
Revised: 26 July 2023
Accepted: 27 July 2023
Published: 30 July 2023

1. Introduction

According to UN studies, by 2025, more than half of the states will either experience a serious water shortage or feel its lack, and by the middle of the 21st century, three-quarters of the world's population will not have enough fresh water [1]. According to experts, by 2030, approximately 47% of the world's population will be under the threat of water scarcity. If in 2000, the shortage of fresh water, including agricultural and industrial needs, was estimated at 230 billion m^3/year, then by 2025, this deficit on the planet will increase to 1.3–2.0 trillion m^3/year. Before the lack of water, poor and rich countries with developed economies were equal to a certain extent. These problems are most acute in Germany, Spain, the Netherlands, France, China, India, Nigeria, Egypt, Kuwait, and Saudi Arabia [2,3].

To date, there are a large number of countries where the shortage of water resources is recorded, for instance, Egypt, Qatar, India, Israel, Lebanon, Iran, Jordan, Libya, Eritrea, UAE, San Marino, Bahrain, Pakistan, Turkmenistan, Oman, Botswana, Afghanistan, Ethiopia, Nigeria, Haiti, and others. At the same time, the demand for water worldwide is growing, while water resources are being depleted, and this problem is more clearly reflected in a number of the countries mentioned [4].

Groundwater is one of the specific types of mineral wealth, an important resource for life support, development of industry and agriculture [5–7]. In terms of increasing deterioration in the quality of surface water, the use of groundwater has several advantages due to their high resistance to climatic factors, protection from pollution, relative stability of quality and quantity over time, absence in most cases of the need for water treatment and seasonal restrictions in their use, etc. [8,9].

The features of groundwater, primarily their renewability, are the reason for a wide discussion in the natural resource and legal literature on the advisability of classifying them as minerals.

Issues of legal regulation of relations related to groundwater were considered mainly by specialists in the field of jurisprudence. A detailed analysis of approaches to the issue of groundwater as an object of law was carried out in the works of E.N. Mukhina [10]. According to one point of view, legal regulation of groundwater is subject simultaneously to two branches of law—mining and water (such Soviet specialists like A.A. Ruskol, N.A. Syrodoev, L.A. Zaslavskaya [11,12]), the other—only water (soviet scientists O.S. Kolbasov, N.B. Mukhitdinov [13,14]) [15].

The ideas about the legislative and regulatory framework for the study and extraction of groundwater, based on the issues of hydrogeological research as a branch of geological knowledge, are reflected in the works of V.V. Antonov, B.V. Borevsky, N.V. Sedov, V.P. Strepetov, L.S. Yazvin [16,17].

The Constitution of the Russian Federation is the main legislative act in the field of regulation of subsurface use of underground drinking water.

Currently, several problems can be named: due to the decrease in state financing of geological exploration, there is a decrease in the volume of reserves and the number of explored deposits of drinking groundwater [18]; transition to the use of surface waters; poor quality of drinking water in several regions of the Russian Federation due to the excess content of elements such as iron, manganese, strontium, fluorine, lithium, silicon, boron and bromine [19].

In work [2], the authors indicate that the total amount of groundwater reserves suitable for use (drinking and domestic, industrial, and technical water supply, land irrigation and watering of pastures) is about 34 km^3 per year. In Russia, the availability of forecast groundwater resources is 6 m^3 per day per person. At the same time, several subjects of the Russian Federation are experiencing a significant water shortage due to the uneven distribution of groundwater resources. The trend of such unevenness concerns not only Russia but also such states as China, France, Italy, Germany, the countries of Central Asia, etc. [2].

The share of groundwater use for drinking and household needs in the total volume of produced water is 69% [2]. Fresh groundwater is often the only source of providing the population with high-quality drinking water compared to surface water. Water supply for more than 50% of the territories and population of the Russian Federation is carried out at the expense of groundwater [2].

It should be noted that at present, in several regions, there is a deterioration in the quality and pollution of groundwater. The researchers note that often sources of pollution are waste and wastewater storage sites, large municipal solid waste landfills, construction sites, oil fields and oil depots, industrial sites, etc. [20–22].

The problem of individual water supply arose in Russia in the late 80s—early 90s. and still has no logical systemic solution. The active growth of suburban construction, associated with the privatization of lands of the unallocated land fund, as well as the transfer of land from agricultural use to the category of private housing construction (PHC), led to the mass development of large areas, not only as a residential sector but also as industrial facilities of various class and type. The structure of centralized water supply, adopted as the basis of water supply in the Soviet period, could not solve the issue. Market relations in the national economy collapse of the state planning system have led to a sharp rise in the cost, and often to the impossibility of connecting new cottage settlements, gardeners' non-commercial partnership (GNP), suburban settlements (SS) and enterprises to water supply systems. Many enterprises that ensure the operability of centralized water supply systems have declined due to systemic non-payments, rising costs for equipment modernization and the outflow of qualified personnel. A similar situation, to some extent, has developed in the structure of gas supply to the population, but over the past five years, positive changes have been observed in this area.

The mechanism of market relations, adopted as the basis of economic policy in the early 1990s, contributed to the creation of an entire industry of individual water supply. In the process of privatization and subsequent bankruptcy of most public sector enterprises involved in the construction and operation of water intake facilities, thousands of private drilling and construction companies, cooperatives and just individual entrepreneurs appeared, which quickly responded to the increased demand for drilling water boreholes, building wells, capturing springs.

As a rule, the first enterprises of this area possessed specialized professionals who had been released from the public sector, as well as equipment, technologies and materials that corresponded to the tasks set. In the mid-1990s, such types of work as drilling boreholes and building wells were subject to mandatory licensing, and requirements for the performers of the work were very stringent and largely justified. In the mid-1990s drilling water wells was subject to mandatory licensing, but since the 2000s, the situation has deteriorated significantly. It led to the emergence of many low-skilled diversified organizations that do not know the specifics of subsoil use and technologies for constructing complex engineering facilities, such as water wells.

Private water wells, which number in the thousands in each region, are currently not subject to official registration. As a rule, they do not have any geological and technical documentation. An attempt to license individual water wells was made in the late 1990s and early 2000s but had no further continuation. Licenses were issued to individuals for 25 years, particularly for artesian strategic aquifers.

The Law of the Russian Federation "On subsoil" [23], the basic legislative act in subsoil use, has undergone numerous changes, additions, and adjustments. However, it currently prohibits individuals from equipping water wells with aquifers that are a source of centralized water supply.

The problems of implementing supervisory activities in groundwater extraction by individuals were considered earlier in the works [3,8,24].

Melnikov's work [3] emphasizes the lack of regulation on the issue of groundwater extraction by individuals. In our opinion, the author rightly highlights the obligation of persons drilling wells for water to provide reliable and complete information about service. This measure may:

1. Reduce unauthorized extraction of groundwater by private individuals;
2. The state authority exercising control and supervision over the sphere of relations under consideration would be able to assess groundwater reserves more accurately.

Russia's problem is that over the past 30 years, many errors and inaccuracies have accumulated in groundwater resource management. Aquifers used to supply water to their houses by individuals are often referred to as sources of centralized water supply for infrastructure facilities and settlements. Underestimation of this factor and the formalization of many legislative approaches will create a big problem when there is an urgent need to put groundwater reserves on the regional register. Therefore, a way out of the contradictions accumulated in recent years in legislative acts and regulations, allowing to legalize individual boreholes and wells equipped with drinking aquifers, should be found.

Thus, the study aims to identify the problems of groundwater extraction by private individuals (organizational, economic, and regulatory aspects) and find ways to solve them. The main focus of the article is the regulatory mechanism in the Russian Federation. However, international experience in allowing individuals to extract groundwater on their plots of land is also of interest. These issues are especially relevant in the current economic and geopolitical conditions, given the strategic importance and need for groundwater resources for various needs.

To achieve this goal, we aim to answer the following research questions:

(1) What national norms and regulations govern the exploitation of groundwater resources in the Russian Federation?
(2) Are there any real examples illustrating the scale of the problem of underestimating the amount of groundwater produced by private individuals?
(3) What state control and regulation systems of groundwater extraction by individuals exist in different countries?
(4) What measures should be developed to improve legislation and strengthen control over groundwater extraction to increase economic and social benefits for the population and the state?

To answer these research questions, we organized the paper as follows: we conducted a desk study that involved a comprehensive review of academic literature on the state administration in the field of individual water use, particularly extraction of groundwater for own needs. We defined recent changes in national legislation and their consequences. To confirm the identified organizational, economic, and legal problems, monitoring, collection, and analysis of data obtained from the Territorial Fund of geological information (TFGI) and factual materials on water intakes of the Leningrad region was carried out. We also compared the state approach to groundwater extraction by private individuals in other states (mainly in the example of Germany and China). Finally, we have identified ways out of the current situation in Russia's private groundwater supply sector.

2. Materials and Methods

This study uses a comprehensive method that includes analysis and generalization of data provided in publications of Russian and foreign authors and periodicals, industry publications and bulletins, laws and regulations, reports of government hearings, UNESCO materials [1], and a consultative method with leading foreign experts.

In general, this study's main materials and methods are regional statistics, field studies, comparison method, collection, processing, and analysis of registration documents in the TFGI, analysis of water use volumes for individual regions under study, and balance method.

The research methods are characterized by an interdisciplinary approach based on economic, legal, hydrogeological, technical, technological, and environmental factors. As a result of the study, fundamentally new approaches in the federal management of groundwater extraction by individual subsoil users have been developed.

To solve the problem of managing subsoil use by individuals, the structure of the Territorial Fund of Geological Information (TFGI) is of paramount importance in terms of replenishing geological information, coordinating services and committees for issuing permits for water use, legal and administrative tasks in the process of organizing the system water supply for out-of-town construction.

Acquisition of a unified information base of geological factual material, digitalization of the process, and analytical and expert processing of hydrogeological data collection is an integral task of the TFGI in solving the problems of the individual water supply of suburban areas in modern conditions.

In the process of interviews with TFGI staff, it turned out that thousands of individual well water intakes are not registered in most cases. Most of them are not licensed and are not controlled by government agencies. In addition, it turned out that the unified database of geological information is quite outdated, so it needs to be updated.

For a visual representation of the current situation in the groundwater withdrawal field in Russia, it is advisable to refer to statistical data on groundwater use in the Leningrad region. The results of the statistical analysis are shown in Section 3.2.

3. Results

3.1. Analysis of Contradictions in the Legislative Framework

For a more thorough analysis of the framework regulating groundwater extraction, special attention should be paid to the new Russian State Standard GOST R 59054-2020 entitled "Classification of water bodies", introduced on 1 April 2021 [25]. This document applies to both groundwater and surface water. The introduction of GOST compromised identifying groundwater intakes, including centralized requirements for sanitary norms and rules in terms of security. For domestic and drinking water intakes, there are strict requirements for compliance with sanitary protection zones (SPZ) of I, II and III belts, in contrast to purely technical water intakes, where these requirements are not mandatory [26].

The paradox is that during the Soviet era, domestic and drinking water supply had a clear and unambiguous definition—a requirement for the intended use. It allowed the use of drinking-quality water not only to satisfy the physiological needs of a drinking resource but also contained the conditions for using this class of resource for irrigating gardens, greenhouses, plants, watering livestock and poultry, bathing and washing up, in sanitary facilities, and washing dishes etc. In this regard, rather high requirements for the allocation of SPZ, in particular, the I belt (50 m in radius for non-pressure, and 30 m for artesian aquifers) in dense rural areas with the high cost of land and the difficulty of allocating land allotment, a very common problem arises regarding the licensing of water intakes for domestic and drinking water supply. Such licensing and refusal to issue licenses are widespread, especially in preparing documentation in gardeners' non-commercial partnerships and suburban settlements. Repeated attempts to circumvent such high requirements through the substitution of concepts were made. So, even in the latest editions of the Law "On subsoil" [23], the concept of "domestic and drinking water supply" was replaced by "domestic water supply", which, in essence, does not solve the problem. According to paragraph 4.2 of GOST, new classifications by types of water use have been presented [25].

GOST provides a classification of water bodies according to the purposes of water use. A part of the classification is presented below (Table 1). It illustrates a misunderstanding of the requirements for preparing license documentation for water intake facilities.

Table 1. Classification of water bodies according to the purposes of water use in accordance with GOST R 59054-2020 [25] (fragment).

Purpose of Water Use		Type of Water Body
Household and drinking and household needs of the population	Drinking and household water supply of residential areas and the population of public buildings: urban industrial areas; agricultural areas	Source of drinking water supply
	Air conditioning in public and residential buildings	Source of technical water supply Source of drinking water supply
	Watering and washing the territories of settlements (streets, squares, green spaces), operation of fountains, etc.	Source of drinking water supply
	Watering plantings in urban and rural greenhouses and greenhouses	**Source of technical water supply** Source of drinking water supply
	Other needs (including extinguishing fires, flushing water and sewer networks)	Source of technical water supply
The needs of agricultural production (without irrigation and watering)	Watering plantings in warm houses and greenhouses	**Source of technical water supply** Source of drinking water supply
Irrigation and watering	Irrigation: oasis; regional	**Source of technical water supply** Source of drinking water supply
	Irrigation (pastures)	**Source of technical water supply**

Based on the results of the analysis of Table 1, the following conclusion can be drawn: sources of technical water supply (water intake wells and wells) that cannot allocate SPZ on a territorial basis, regardless of the conditions of occurrence and the chemical (microbiological) composition of groundwater, can be licensed as technical water intakes, and the water resource can be used, as indicated in GOST, for irrigating gardens, greenhouses (including urban ones), irrigating green spaces, flushing water and sewer networks, technological needs for processing agricultural products, etc.

Thus, it is allowed to use technical water in growing food crops, washing them, etc., and using water supply networks. This means that when obtaining a license for technical water supply, it is allowed not to allocate SPZ of all belts, laying technological water pipelines according to water supply schemes for the residential and non-residential sector, including in the territories of GNP and SS, if this resource is designated as technical.

In GOST, it is presented that in the intended use, "Industrial needs (without thermal power)" indicates that the manufacture of food products, chemical and pharmaceutical preparations is possible from a source of technical (industrial) water supply [25]. This point raises several questions and requires clarification.

Paragraph 3.11 of GOST contains the following definition: "Technical water is water supplied using a centralized or non-centralized water supply system, not intended for drinking, cooking and other household needs of the population or the production of food" [25].

Reference Annex A of GOST contains the classification of aquifers (first, second and other aquifers) [25]:

1. in order of location from top to bottom along the section from the earth's surface;
2. by the presence or absence of hydraulic connection with surface water bodies;
3. if possible, the use of aquifers as sources of centralized water supply.

Summarizing the above, we conclude that subsoil users, individuals extracting groundwater for their own needs, can be divided into two categories:

- ✓ Those who do not violate the Law "On subsoil", exploit aquifers that are not a source of centralized water supply. As a rule, this is the so-called "perch water" or ground aquifers, that is, aquifers of active water exchange. Such aquifers have a variable chemical and microbiological composition, have low filtration characteristics, and are highly dependent on atmospheric nutrition;
- ✓ subsoil users who unknowingly or deliberately use groundwater from aquifers for which centralized water supply has already been or will be organized in the future. Such aquifers include waters of primary sediments, intermorainic Quaternary aquifers, alluvial aquifers confined to river valleys, fissure-vein waters associated with tectonic faults, deepened ancient valleys, artesian regional aquifers, which are part of artesian basins of various kinds.

It is important to note that during the operation of groundwater aquifers, a whole host of technological problems arise, associated not only with the need to carry out water treatment, including biological pollution typical for rural areas but also with the need to use complex water intake filters in wells, which is defined as a rule, with a fine-grained composition of the host rocks and the properties of the so-called "quicksands".

A set of such problems forces water users to look for a more reliable source of water supply, which are the main aquifers on the balance of state accounting. The interests of drilling companies fully coincide with this state of affairs since guarantees for the operation of a water well can only be given when the filtration parameters of the aquifer can ensure a stable mode of operation of the water intake.

The occurrence interval of aquifers used for centralized water supply, their distribution area, filtration parameters, boundary conditions for nutrition, and interaction with neighboring aquifers are within the competence of hydrogeologists. With the current practice, there is often no understanding of what kind of aquifer is used by the customer—an individual, there is no control over subsoil use and the qualifications of performers—drilling organizations.

Geological structures, aquifers, for example, in the Leningrad region, are not always unambiguous interpretations. First, this applies to the Quaternary intermoraine aquifers; the distribution area, occurrence interval, particle size distribution, and filtration characteristics are very variable. The geomorphology of, for example, the Karelian Isthmus is a rugged relief, and the presence of Quaternary glacial structures makes it very difficult to identify the aquifer. So, as an example, we can cite the presence of ancient over deep valleys, the location of which is not fully understood. Even though the aquifers of alluvial structures have very high filtration characteristics, some have high pressure (up to self-outflow) and can be a source of centralized water supply. There have been cases of active self-discharge when wells penetrate similar structures. However, the existing rules allow the construction of water wells on aquifers that are not a source of centralized water supply and are located at shallow depths [27].

Moreover, the first aquifer from the surface, which is not a source of centralized water supply, can become such with sufficient geological study and the appearance of centralized water intakes in the study area. At the same time, private wells drilled to such aquifers automatically become illegal.

On the other hand, in the Leningrad region, Volosovsky, Gatchinsky and other areas, the Ordovician aquifer is the first from the surface. Free-flowing aquifer lies at a depth of 15 m from the earth's surface. The aquifer is on the balance sheet. It is a source of centralized water supply. However, any private well or delve in these areas violates the Law "On subsoil". No so-called "ground" or Quaternary aquifer exists, and the number of individual water intakes is in the hundreds. This state of affairs is explained by the lack of centralized water supply systems and the intensive development of agricultural territories with cottage settlements and gardening. Quaternary aquifers are more vulnerable than primary aquifers. Still, in Russia, quaternary aquifers sometimes have a thickness of up to 100 m due to the diversity of aquifers, so we raise this topic not only in the context of quaternary or ground surface waters but also in primary aquifers. In Russia, quaternary aquifers also belong to centralized water supply systems. Each aquifer is unique in its properties, degree of protection, chemical composition, and dynamics.

The problem of assessing groundwater reserves in subsoil plots operated by single water intakes has been ongoing for over a decade. For a long time, these included water intakes located within the same water intake unit with a relatively small water intake. At the same time, the definition of the concept of "single (small) water intake" was first proposed in 2014 by such specialists as Borevsky B.V., Yazvin L.S. [28].

The authors note that "in the 1970s–1990s, single water intakes, for which groundwater reserves were not approved and were not registered by the state, accounted for about 50% of the total water withdrawal. Before the adoption of the Law of Russian Federation "On subsoil" in 1992, the operational reserves of groundwater for such subsoil plots were not assessed; design and construction were carried out according to "Permits for special water use" issued based on hydrogeological reports [23].

In such reports, the proposed section was described in a very short form, and the depth, well plan and flow rate of the project well were indicated. The lowering of the level was determined by calculation. The characteristics of water quality and other data necessary for design were given. When using several aquifers on one water intake unit site, the indicated characteristics were given for each.

The Law on subsoil" initially made one exception to the requirement to estimate reserves. According to Art. 19, owners, land users and tenants of land plots have the right within their boundaries to carry out "... the installation and operation of domestic delves and wells on the first aquifer, which is not a source of centralized water supply, in the manner established by the relevant executive authorities of the constituent entities of the Russian Federation" [23].

3.2. Underestimating the Amount of Groundwater Produced by Private Individuals—Numerical Example

In accordance with the research question N 2, it is proposed to consider examples of groundwater management activities of two large horticultural arrays in the Vsevolozhsk district of the Leningrad region. In the first case, this is part of the so-called "Beloostrov massif", located 30 km from St. Petersburg along the "Scandinavia" highway. On the considered area of 31,994,000 m^2, there are 60 operating GNP with a total number of built-up plots of 12,243. The number of licenses obtained for groundwater extraction for domestic and drinking water supply is four pieces with a production volume of 12 to 70 m^3 per day. Four more wells are registered in the Territorial Fund of Geological Information (TFGI), which extract groundwater for domestic and drinking water supply. Still, licenses for them have not yet been obtained. Based on the data of registration cards, water intake from them can be carried out from 130 to 360 m^3 per day. On the territory of the massif, two aquifers suitable for domestic and drinking water supply are registered—the Verkhnekotlinsky aquifer of the Upper Proterozoic (160–180 m) and the Quaternary intermoraine aquifer (25–45 m from the earth's surface).

Assuming that all registered water withdrawals will eventually be licensed, the total withdrawal from all eight wells will be 1035 m^3 per day (881 m^3 per day without a license and 154 m^3 per day with a license). The consumption rate of household and drinking water resources in rural areas, excluding water consumption for watering vegetable gardens for buildings without internal equipment with a water supply and sewerage system, is 50 L per person per day. With 100% occupancy (during the summer period) of all built-up households in the amount of 12,243 in the study area, with conditionally settling two people per building, the total consumption is obtained:

$$12{,}243 \times 2 \text{ people} \times 0.05 \text{ m}^3/\text{day} = 1224.3 \text{ m}^3/\text{day} \quad (1)$$

Thus, today, with the officially permitted production volume of 154 m^3/day, water resource consumption can be more than 1200 m^3/day, excluding irrigation of agricultural plantations. Four water wells, which have licenses for domestic and drinking water supply with a total capacity of 154 m^3/day, cannot meet the population's needs in the water resource. Even if we add four more registered wells to the calculations, which do not yet have a license, the water demand of the massif cannot be satisfied, especially since there are 60 GNP in the massif, and the number of officially existing wells is eight. However, the majority of wells are over 30 years old. Thus, the needs of the population are provided, according to official statistics, by 13%.

A similar situation is observed in the horticultural area "New Toksovo" of the Vsevolozhsk district of the Leningrad region, where 28 GNP are located on an area of 11,421,000 m^2 with a total number of plots of about 8500 pieces. There are only two licenses issued for the massif, with a total production of 585 m^3/day, and there are seven more wells with registration cards without the right to extract groundwater with a total estimated flow rate of 635 m^3/day. Having made a preliminary calculation of the total water demand of the array, we get the following:

$$8500 \text{ plots} \times 2 \text{ people} \times 0.05 \text{ m}^3/\text{day} = 850 \text{ m}^3/\text{day} \quad (2)$$

As a result, two water wells with a capacity of 495 m^3/day and 90 m^3/day for 28 GNP with a total of 8500 sites are not enough, not to mention that the license issued to one legal entity (GNP) does not imply the supply of water resources to neighboring GNP, which are other legal entities.

The conclusion from the situations that have developed with the provision of water resources suggests one: the population of suburban facilities independently provides for its own needs for drinking and technical water (at its own expense).

The choice of examples of two arrays is largely non-random. In both cases, only two aquifers (primary Kotlin sandstones and Quaternary intermoraine sands) can be a source of water supply, which are a source of centralized water supply.

In the Leningrad region, there are similar GNP massifs that do not have a single license for groundwater extraction. However, the number of built-up plots is calculated in the thousands.

3.3. State Control and Regulation of Groundwater Extraction by Individuals Exist in Different Countries of the World (Cases)

Within the framework of this study (research question N 3), it is proposed to briefly refer to international experience in organizing groundwater supply by private individuals. First of all, it is worth noting the difference in approaches to drilling water wells by private individuals in various countries from the point of view of the national legislative framework. In some countries, this is strictly prohibited by law. In others, it is allowed, but with restrictions. In some states (for example, African countries), groundwater extraction is not controlled by the government. However, it is important not to confuse the concepts of private groundwater supply in summer cottages and centralized water supply, which is widely used in cities. The key point is the issue of subsoil ownership in various states

Over the past 25–30 years, more than 300 million wells have been drilled worldwide for water extraction. Only in the United States annually, are about a million wells drilled, the waters used for household needs, irrigation, and technical water supply. The depth of production wells varies considerably and is determined by the specific hydrogeological conditions of the territories. Usually, it is 100–200 m, rarely reaching 800–1000 and even 2000 m [29].

Of scientific interest is the foreign experience of European countries, for example, Germany, which is supposed to be one of the most developed countries in the world. The methodology in the field of geological study and extraction of groundwater is one of the most advanced in Europe. A rational approach to the management of groundwater resources and environmental management plays a special role in the field of groundwater extraction there. The share of groundwater use in Germany reaches 75% of consumption for household and drinking purposes and industrial water supply.

The fundamental points that are a priority for German specialists in the field of hydrogeological study and extraction of groundwater are, first of all, the principle of rationality. Secondly, safety, and thirdly, control.

The fundamental document regulating the principles of water supply in Europe is Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, which establishes framework provisions for Community activities in the field of water policy [30].

Sanitary protection zone I (Fassungszone) in Germany has a radius of 10 m [31]. At the same time, in Russia, the minimum radius is 30 m. With a diameter of 60 m, the area for water intake occupies an area of about 3600 m^2, making it impossible for individuals to obtain a license. This moment is the main reason for the ban on issuing a license to individual water users in Russia.

The model of licensing agreements in Germany implies a short, direct relationship between the customer and the Water Department. When paying the license cost (fixed rate), the Department, independently or with the help of invited specialists, performs all maintenance work and, in the final version, issues a license for hard-quota water withdrawal, which is further controlled. This mechanism is convenient both for the customer and for the department itself, which has real information on the volume of water consumption, reserves, and resources of all water intakes in the region.

More detailed data is shown in the example of a federal state located east of Germany—Saxony. According to § 13 of the Saxon Water Law (Wassergesetz-2013 SACHSEN) [32], "Erlaubnis" (permit to operate a small water abstraction) local water authorities, issuing permits in accordance with the program of measures, can periodically check water intakes, if necessary, within a reasonable time.

The process of obtaining a license in the Water Department of Saxony is regulated. For individuals, this procedure is simple and fairly transparent. For the use of waste and drinking groundwater in the Water Department of Saxony, the list of documents for obtaining a license for small water intake consists of the following items:

- a statement indicating the planned volume of water use,
- site plan,
- water intake construction plan.

After receiving these documents from the customer, the Water Department considers the application. First of all, the correctness of the documentation is checked, and then the impact of the licensed water intake on neighboring water intakes is calculated. The Water Department independently performs a report on the impact of the new water intake and also assesses the reserves on the site. Without any negative impact of water intake on the aquifer and neighboring wells, the Water Department issues a license to the customer. For more complex hydrogeological conditions, the Water Board may require additional reports or documents from the customer. If the missing documents are not submitted within a certain period, a license can be refused [33].

When drilling groundwater wells by individuals to a depth of up to 100 m in Saxony, subsoil users should notify the Water Board. After that, they can operate the underground water intake without a license. However, information on water intake is recorded by the Water Department. Water intake is registered and controlled by the monitoring system.

With regard to the process of operating underground water intakes in Germany, it is worth noting that special attention is paid to maintaining water quality. Depending on the declared volume, water users must take groundwater samples at least once a year and check their quality. In case of obtaining a positive expert opinion on the quality of groundwater, production continues. If groundwater quality is low, requires additional water treatment, or the content of harmful substances exceeds the norm and is dangerous for human life. This information is submitted to the Water Department. It is this body that decides the future fate of groundwater intake.

Another international example of groundwater resource management is in France. According to French Civil Code, groundwater is considered private property. However, after this resource was intensively exploited by industries in the 1850s, the State increasingly regulated its use. In 1935, a system of individual access and withdrawal rights, managed by the State, was established to protect deep confined aquifers showing signs of overexploitation. This system of use rights was later extended to unconfined shallow aquifers with the 1992 water law, mainly to protect the environment. A new management approach, based on individual volumetric entitlements, was then developed and tested in several French groundwater basins, obtaining a legal basis in the early 2000s. The 2006 water law constitutes a clear break in French water policy. The system of individual volumetric entitlements managed by the State was cancelled, and users were asked to form Water Users' Associations at the catchment level. Associations became the recipients of pooled water use entitlements, which they lust, share among their members using rules agreed upon collectively. Although this reform only applies to the agricultural sector, it represents a clear shift from a private to a common property regime [34].

Referring to international experience, it is worth citing the example of the People's Republic of China, where, in accordance with the Regulation on Groundwater Management dated 1 December 2021, "the benchmarks for the total production of each province, autonomous region or municipality are set." The subdivisions and individuals that carry out groundwater abstraction must install an online groundwater abstraction metering tool that transmits real-time data to the competent administrative departments of water management; the fine for not having meters is 100,000–500,000 Yuan, as well as the fine for a non-liquidated well. The state is also creating a system of groundwater reserves. Key areas are identified for preventing and controlling groundwater pollution throughout the country [35–37].

The need to regulate the issues of groundwater extraction is an important state task, which is also confirmed by the experience of foreign countries [38,39]. There is a sharp increase in scientific research, the regulatory framework is being updated, and funding for projects related to groundwater management is increasing [40–42].

To conserve strategic groundwater resources, China introduces groundwater extraction restriction zones and takes complete control of the level of groundwater abstraction and creates national groundwater reserves. In addition to China, the United States and Australia are actively conducting educational activities to increase awareness of the importance of groundwater among the population and water users, and much attention is paid to groundwater monitoring during the construction of oil infrastructure facilities [43–45]. In this paper, the emphasis is made on the features of a national system for managing groundwater extraction by individual users. Therefore, the experience of other states is the subject of a separate review study.

4. Discussion

Returning to the purpose of the study, it is further proposed to focus on possible solutions to the problem of individual underground water supply in the Russian Federation. After analyzing several problems in the segment under study, the question of how to solve the problem associated with individual water supply in private areas that do not have centralized water supply and sewerage systems should be raised. To solve this problem, the following provisions should be adopted:

(1) all previously drilled water wells and capped springs should be taken as a source of technical water supply in accordance with the adopted GOST R 59054-2020 [25];
(2) it is necessary to carry out mandatory certification of all existing water intake facilities, regardless of the aquifer on which capturing is carried out, as well as the technical features of water intakes, should contain:
   - ✓ technical and technological description (according to the standards of geological exploration documentation): diameters, intervals, filter type, grouting intervals, pump installation depth and type of water lifting equipment;
   - ✓ geological description for the entire depth of the intake structure;
   - ✓ shortened chemical and microbiological analysis of groundwater;
   - ✓ hydrogeological conclusion on the identification of the source of water supply to a particular aquifer, according to the accepted regional classification;
   - ✓ results of experimental filtration testing to calculate the productivity of a water intake facility;
(3) it is necessary to include registered individual water wells and delves in a unified federal monitoring network;
(4) oblige to introduce a system of periodic monitoring and reporting (periodic analysis of groundwater, measuring levels), as well as accounting for consumption (production) both using a water meter and according to a declared need;
(5) all drilling, construction and exploration companies that provide services to the public in drilling water wells, building wells, and capturing springs, are required to obtain a license for a special type of work with mandatory reporting to the territorial fund of geological information based on the results of production activities. The staff of companies should include geological specialists with diplomas of education confirming the relevant qualifications (geologist, hydrogeologist, geophysicist, technologist).
(6) Establishing a separate body of state control over individual subsoil use is necessary.

The problem of individual private subsoil use, which includes the construction of low-rate water wells, spring capturing, and well digging in their own and adjacent areas, has been insoluble for many years. The Law of the Russian Federation «On subsoil», which has undergone many revisions since the early 1990s, makes it possible to extract underground water in the amount of up to 100 m^3 per day for own needs from an aquifer that is not a source of centralized water supply [23]. In other words, it is allowed to extract water from water seeps of the aeration zone or ground aquifers above the main "drinking" aquifers.

Establishing a maximum allowable daily production volume of 100 m^3 (which is 4000 L per hour) seems unrealistic since such a volume of water cannot be physically developed on a plot of land with an area of 10 acres, even though groundwater itself does not, as a rule, have a protective aquiclude and are subject to possible biological and chemical contamination (e.g., cesspools, various types of fertilizers, etc.) [46]. In the current situation, such a flow rate (100 m^3 per day) can only be provided by an aquifer with sufficiently high filtration parameters (for example, medium-grained sands or weathering crust of bedrocks).

For this reason, most individual developers create a source of water supply from aquifers, which has both the necessary supply of groundwater and the chemical composition of the water resource that meets the user's requirements [47]. Demand gives rise to supply, and the system of control over subsoil use does not properly fix and does not prevent massive violations of environmental legislation.

The way out of the current situation cannot be either unambiguously prohibitive or liberal. The provision of the adopted GOST gives a certain vector to the approach to the legalization of individual water supply. Taking all existing individual low-rate water intakes as a source of technical water supply, i.e., in the absence of SPZ belts I, II and III, as well as in the presence of technical regulations for the construction of water wells and delves, it is possible quite legally and, at relatively low cost, to register a whole segment of individual subsoil use. At the same time, groundwater quality, both in terms of chemical and microbiological composition, can be brought by an individual subsoil user to the required drinking standards using modern water treatment systems based on actual excesses of the maximum allowable concentrations (MAC) for certain components [48].

However, suppose such an approach is adopted in the current legislation. In that case, the construction of new water intake facilities must be carried out strictly according to the project by licensed organizations with obtaining mandatory permits.

According to Borevsky B.V. and Yazvin L.S., "geological exploration and groundwater extraction should be carried out only within the framework of issued licenses for subsoil use [28]. An exception may be granted only to individuals for groundwater extraction on their land plots for their needs. Suppose we establish a minimum fixed value of the limiting water withdrawal for the indicated purposes. In that case, this norm can be extended to the withdrawal of water from the first aquifer and to the remaining aquifers" [28].

According to the definition, the main feature of a single water intake is the localization of a significant impact of exploitation in its immediate vicinity. At the same time, the authors suggest using the following dependence to estimate the radius of the formation of reserves R_f (km) in the case of using single low-rate water intakes [2]:

$$R_f = \sqrt{\frac{\sqrt{Q_v}}{\pi M_{pr}}}, \quad (3)$$

where Q_v is the projected flow rate of a single water intake unit, L/s;

M_{pr} is the modulus of the groundwater resource potential, L/(s·km^2).

This dependence can be the basis for assessing the hydrodynamic impact of individual low-rate water intakes located with high density over large areas.

It is also possible to apply the term "water ingress" to groundwater extraction sites for the own needs of individuals and possibly, in other cases, for single water intakes with a flow rate below the established criterion for such "subsoil plots" [28,49].

Organization and systematization of subsoil use is an urgent and essential task of the state to ensure the safety of subsoil. Groundwater (especially fresh and ultra-fresh) is one of the most essential minerals. In turn, groundwater as a kind of mineral has dynamic characteristics (is in constant motion), has reserves that can only be estimated during the operation of the aquifer, can change its chemical and microbiological composition, as well as resource potential, depending on a large number of factors [50,51].

In the case of groundwater extraction by private individuals for their own needs, legislators allow equipping water intakes to the first aquifer from the surface that is not a source of centralized water supply or to an aquifer located above the so-called “drinking aquifer”. This does not seem entirely correct since the aquifer becomes “drinkable” if the water supply is organized from it, centralized and decentralized, for household and drinking purposes. That is, an individual who has a well or delve risks falling into the category of violators of Law “On subsoil”.

Any intervention in the subsoil, whether drilling a borehole for water, building a well, etc., regardless of the depth and purpose, is part of the exploration activity. In this case, geological documentation, laboratory studies (for example, chemical analysis of water samples), determination of hydrogeological parameters to predict the activity of water intake, and a detailed description of the technology of mining operations and preparation of technical documentation are required.

The statement that the so-called “small” wells and private wells are not of interest for geological documentation of the state’s entire territory is fundamentally wrong. It is based on the description of geological structures in shallow mine workings (not to mention deep ones) that geological and hydrogeological maps of the country are compiled, and the structures themselves are used for monitoring for a long time. Due to the fact that the reliability of geological information affects the backbone of strategic projects, updating data on actual indicators is an integral part of the subsoil use system.

From these positions, it is expedient to organize full accounting and control over all private water intake facilities, the number of which in the country is estimated in millions.

5. Conclusions

As much effort as possible should be made to conserve fresh water sources, as well as to find possible economically less expensive ways to solve the problem of freshwater shortage in many countries of the world, both now and in the future.

In Europe, as in Russia, at the level of federal legislation, there is a ban on drilling water wells in strategically important regional aquifers for individuals. This procedure is characterized by the fact that a private well cannot ensure the safety of subsoil use (because there is a possibility of contamination) since observing the sanitary protection zone on a limited area of private land plots is impossible. The Russian approach in this regard is similar to the world one. Still, individual private water supply practice is characterized by a massive violation of this principle due to economic and organizational factors and geographical scales. An attempt to solve the problem within the legal framework is the goal of this study.

The existing classifications of aquifers (by types of interaction with surface water systems, by serial numbers (according to the adopted new GOST), by intended use (drinking or technical) do not consider the specific features of drinking groundwater as a mineral resource, which significantly weakens the system of management and control over reserves and water use at the state level.

A large number of federal departments take part in regulating the study, protection, and use of water resources in the Russian Federation, among which no one head agency coordinates all issues for groundwater. Due to various departmental subordination, the existing management system does not solve all the tasks facing it. In this regard, the currently observed decentralization of groundwater resource management negatively affects the activities of water companies and the life of the population.

The uniqueness of the Russian structure of water supply for the population lies in liberalization on the one hand and prohibitive policy on the other. That is, the state has shifted the water supply problem for suburban construction to the owners of the housing stock. The population should independently solve the problem of groundwater extraction on their territory. The problem lies in the possibility of access of individual well water intakes to protected aquifers where there are no other water seeps.

In conclusion, it should be noted that any change in the legislation in the field of subsoil use has several aspects, such as economic, environmental, social, constitutional, legal and regulatory. Accordingly, underestimating at least one of them will lead to negative consequences. Knowledge about the subject of research is based on the experience of more than one generation, as well as the experience of foreign countries. The area of groundwater supply has acquired particular importance in recent years, which means that the task of legislative regulation should be solved by competent personnel.

Author Contributions: Conceptualization, E.G. and V.K.; methodology, E.G.; software, P.T. and R.Z.; validation, E.G., V.K. and P.T.; formal analysis, E.G. and P.T.; investigation, E.G. and V.K.; resources, E.G.; data curation, E.G. and R.Z.; writing—original draft preparation, E.G., V.K. and P.T.; writing—review and editing, E.G. and V.K.; visualization, P.T.; supervision, E.G.; project administration, E.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data sharing is not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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