Modern state of fresh groundwater regional researches

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Abstract: Regarding international handling of regional hydrogeological investigations, there are five main concerns: General groundwater formation and distribution regularities, including the study and mapping of particular regions and large river basins; Regional assessment and mapping of the groundwater discharge; Regional assessment and mapping of fresh groundwater to understand how best to protect the resource from anthropogenic contamination; Studying the groundwater role as it applies to total water resource balances of particular regions, including seas and oceanic coastal zones; and The assessment and study of transboundary aquifers, to determine prospective use for water supply and irrigation of the adjoining territories. Short characteristic analysis of current regional researches state was considered.
Groundwater discharge quantitative assessment and natural groundwater resources were examined, helping to determine the major recharge values of aquifers, which form in various natural and anthropogenic conditions. Also, the groundwater role in general water resources and water balance was quantitatively characterized.
This paper follows the consideration of a new research line, "marine hydrogeology", whose goal is to study the interaction between groundwater and seawater.
Any investigations of anthropogenic pollution consider the danger of different pollutants penetrating the groundwater, and provide a basis for working out methods of fresh aquifer protection.
The primary objectives of transboundary groundwater studies are to provide prospective determination of the practical use of the groundwater, protecting against depletion and pollution.

Keywords: groundwater, water balance, groundwater discharge, vulnerability, transboundary aquifers, natural water resources

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Riassunto: *In questo lavoro sono esposte alcune caratteristiche peculiari delle acque sotterranee come le risorse rinnovabili e le risorse idriche significative, ed i componenti del bilancio idrico nelle differenti regioni.*
Viene mostrato il ruolo delle acque sotterranee per il rifornimento delle acque per uso pubblico e per l'irrigazione nelle diverse aree.
Si possono distinguere nel campo delle ricerche idrologiche regionali cinque aspetti principali associati tra loro.
Essi sono i seguenti: la formazione generale delle acque sotterranee e la regolarità nella distribuzione studiata attraverso la mappatura idrologica di particolari regioni e di grandi bacini fluviali; la valutazione a scala regionale e la mappatura del deflusso delle acque sotterranee; la valutazione a scala regionale ed il monitoraggio cartografico della protezione delle acque potabili sotterranee dalla contaminazione antropica; lo studio del ruolo delle acque sotterranee nel totale delle risorse idriche ed il bilancio idrologico di particolari regioni, che includono le zone costiere di mare e oceani; la valutazione e lo studio degli acquiferi di transizione in funzione del loro sfruttamento per la fornitura di acqua potabile e l'irrigazione dei territori circostanti. Viene presa in esame un'analisi delle ricerche in corso a scala regionale sui temi sopra esposti.
L'attenzione è rivolta alla valutazione della quantità di deflusso e delle risorse naturali delle acque sotterranee, per le quali sono determinati i valori maggiori di ricarica degli acquiferi, che si formano in svariate condizioni naturali e antropiche. Nell'articolo è caratterizzato quantitativamente il ruolo delle acque sotterranee nel bilancio generale delle risorse idriche.
Nel testo viene presa in considerazione una nuova direzione nelle geoscienze. Questa linea di ricerca è detta "idrogeologia marina", il cui fine è studiare l'interazione tra le acque sotterranee e quelle marine.
L'indagine sulla protezione delle acque sotterranee dall'inquinamento antropico partendo dalla superficie del suolo considera la pericolosità la penetrazione di differenti inquinanti nelle acque sotterranee ed elabora un metodo per la protezione degli acquiferi di acqua dolce. Sono considerati obbiettivi primari gli studi degli acquiferi transfrontalieri che forniscono una prospettiva nella determinazione dell'uso pratico delle acque sotterranee senza il loro sfruttamento e inquinamento.

Introduction

Groundwater, as a source of domestic and potable water supply, has several advantages over surface water. It is, as a rule, characterized by higher quality (such as the availability of components necessary for human vital activities), as well as better protection from pollution and evaporation. Groundwater resources, due to availability of regulating capacities, are not subjected to multiannual and seasonal fluctuations. In some northern and arid zones, where surface Water flows freeze up or dry up in some periods of a year, groundwater is the only water supply source. In many cases, it is possible to abstract groundwater in the direct vicinity of a consumer. As consumption grows, well fields

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can be implemented gradually, whereas hydrotechnical construction for surface water use usually requires a large one-time expenditures. These circumstances have predetermined a considerable increase of groundwater use for potable and domestic supply, which, if compared with surface water, dictates that we must take into account its better protection from contamination.

At present, groundwater is the main source of domestic-potable water supply in most European countries. Thus, the groundwater portion of the domestic-potable water supply exceeds 70% in Austria, Armenia, Byelorussia, Belgium, Hungary, Georgia, Denmark, Lithuania, Switzerland and Germany, and amounts from 50 to 70% in Bulgaria, Italy, Portugal, Ukraine and France. Groundwater supplies rural areas, small and large towns, and, in some regions, cities with population exceeding one million people. Groundwater is widely used in municipal water supply in the United States; in the 1970s, groundwater provided more than 40% of municipal water supply. Today, groundwater is used in 75% of municipal water supply systems, providing more than a half of the population in the country with potable water. The same importance of groundwater is also found in the domestic and potable water supply in Australia and some countries of Asia and Africa (China, the Yemen, Saudi Arabia, Tunis, Libya, etc.).

Fresh groundwater is used for industrial processes in many countries. Although this use is justified when potable water is required according to technology (i.e. in the food industry), using drinkable groundwater in industrial processes where there are no requirements in regards to water quality, especially in the areas with a deficit of fresh groundwater, is hardly equitable. In countries with arid and semiarid climates, groundwater is used for irrigation (like southern and western areas of the United States, Spain, Greece, Iran, India, the Yemen and some other areas of Africa and Asia).

Groundwater is in constant and close interaction with water-enclosing rocks on one level and surface streams, reservoirs, seas, landscapes, and vegetation on the other.

Groundwater, being part of the natural world, is in complex and varied interaction with other components of the environment. Because of this, groundwater, particularly its intensive exploitation, significantly affects the environment. Intense groundwater withdrawal causes land surface subsidence, promotes activation of karst suffusion processes, affects river water content, and causes land drainage. Groundwater level determines the character of vegetation, affects productivity of crops, and dictates the necessity of drainage measures underneath buildings. Annual and perennial groundwater level fluctuations can cause flooding of urban and agricultural territories and incite landslides.

In the opposite direction, groundwater is effected by other components of the environment, particularly those that are under intense anthropogenic impact. Spring floods intensify groundwater recharge in the river valleys, and hence increase their natural resources and, at the same time, surface runoff regulation by water reservoirs results in a decrease of flood intensity and duration, and causes a change in the regime of aquifer recharge. This reduces groundwater resources and causes a decrease in the use of well-field exploitation. Extensive development of land improvement, including irrigation and drainage, cause groundwater resources to increase in adjoining territories.

Groundwater has a number of specific features. Its sustainability in the course of the general water circulation radically distinguishes them from all other natural resources. Another essential feature of groundwater is its mobility and close interrelation with other components of the environment (as previously stated) such as atmospheric precipitation, river drainage, water reservoirs, seas, landscapes, and vegetation. These features dictate the necessity of carrying out large-scale regional researches, directed to study groundwater formation and distribution regularities, resources, and quality in various natural, climatic, and geologo-structural conditions.

It is necessary to note that several branches of hydrogeological science were generated in the middle of the last century. Among them was the regional hydrogeology aimed at studying formation regularities of groundwater in large regions (river basins, hydrogeological structures, separate countries and continents).

When compared to other countries, problems of regional hydrogeology were always of primary importance in Russia. In the USA, Germany, and France, more attention traditionally was paid to water inflow calculation in chinks and mountain developments, or to an estimation and prevention of groundwater pollution on concrete sites, or the creation of artificial groundwater.

Only during the last decades have large regional hydrogeological maps been prepared in some countries, like "the Groundwater Atlas of the USA" (Ground Water Atlas of the United States, 1992), or "a Hydrogeological Map of China"; 1:4.000.000 scale (Hydrogeologic map of China, 1:4.000.000, 1980). At present, the hydrogeological world maps at 1:50.000.000 and 1:25.000.000 scales have been created under the auspices of UNESCO.

With collected knowledge, it is now possible to mark five basic directions of regional hydrogeology: 1) to study the general formation and distribution regularities of groundwater, creating hydrogeological maps of the country's territory and its large regions and river basins; 2) a regional estimation and mapping of groundwater discharge; 3) an estimation and mapping of fresh groundwater protection from anthropogenic pollution; 4) to reveal the role of groundwater in the general water resources and water balance of particular regions, including coastal zones of the seas and oceans and 5) to determine the prospects of groundwater use from transboundary aquifers for water supply and irrigation of adjoining territories. The short characteristic of current state researches is given hereafter.

General Groundwater Formation and Distribution Regularities

The basic object and subject of regional hydrogeology research is groundwater and hydrogeological conditions of particular regions and the Earth as a whole. Its goal is to reveal the regional distribution and regularly occurring conditions of groundwater, its changing properties and qualities, features of water movement, regime, and balance; resources and groundwater genesis in various natural, climatic, geological and anthropogenic conditions. Thus the attention is paid both to regional regularities of groundwater distribution, and to groundwater storage formation features.

Groundwater formation and distribution regularities are stated in the works of Semikhatov A.N., Ilyin V.S., Savarensky F.P., Kamenskiy G.N., Tolstikhina M.M. and Tolstikhin N.I., Ovchinnikov A.M., Shvets V.M., Zajtsev I.K., Vsevolozhskij V.A., Kirjukhin V.A. and other Russian scientists (Zektser I.S., 1977, Zektser I.S., Dzhamalov R.G., Mesheteli A.V., 1984, Zektser I.S., Dzhamalov R.G., 1989, Zektser I.S., 2001). During the last decades, they have developed and scientifically proved principles of hydrogeological classification and mapping. The main principles of hydrogeological mapping and hydrogeological map classification are considered in (Nikitin M.R., 1974, Novoselova L.P., 2004). Generally, hydrogeological maps are divided between general maps (actually hydrogeological maps) and specialized or branch maps. Hydrogeological maps can be classified by several features, including the meeting of certain specifications, purpose, scale and territorial coverage, various methods of presentation and others. Among small-scaled maps published in recent years, it is important to note the World Map of Hydrogeological Conditions and Ground Water Flow, 1:10.000.000 scale, edited by UNESCO (1999). This map has dual purpose: on the one hand, it reflects the general hydrogeological conditions of groundwater formation and distribution, structure of aquifers and groundwater quality, and other factors of their genesis; and on the other hand, it characterizes fresh groundwater resources. Such unification allows scientists to receive the most complete representation of groundwater and regional groundwater discharge of large river basins, platform and rock crinkled structures, and basins of certain seas and oceans.

At present with due consideration to the collected factual material, the need for more large-scaled general hydrogeological maps has escalated (a scale of 1:2.500.000 or even 1:1.000.000). Or perhaps it could be an atlas, which would reflect the specificity of fresh- and salt-groundwater formation in various regions in conditions displaying climate change and an increasing influence of anthropogenic factors.

The Regional Assessment and Mapping of the Groundwater Discharge

The regional quantitative groundwater discharge assessment is usually accompanied by creating specialized maps of various scales. It represents considerable interest for geosciences, especially hydrogeology, hydrochemistry and a hydrology. Results of this assessment reveal formation and distribution regularities of groundwater discharge in various natural, climatic, and hydrogeological conditions that can form a basis for predicting of underground hydrosphere changes under the climate changes and increasing anthropogenic load influence in the zone of active water exchange (Hublaryan M.G., Putyrskii V.E., Frolov V.P., 1987). The quantitative data about groundwater discharge determines the groundwater role in the general water resources and water balance of various regions. This data is of great significance, as it helps to work out schemes of groundwater complex use and protection.

In the practical aspect, natural groundwater resources characterize the top limit of possible groundwater withdrawal for the long-term period without their depletion (except for coastal water intakes of infiltration type) (Zektser I.S., 1977).

The regional groundwater discharge assessment and mapping (in small scale) was executed in the Soviet Union for the first time in the early sixties by a group of hydrogeologists and hydrologists under the direction of prof. B.I. Kudelin. Published maps of 1:5.000.000 scale, such as the Map of the Groundwater Discharge of the USSR and the Map of the Groundwater Discharge of the USSR in Percentage of the General River Runoff, (Karta podzemnogo stoka SSSR v procentah ot obshego rechnogo stoka i koefficientov podzemnogo stoka v procentah ot osadkov, 1964; Karta podzemnogo stoka SSSR, 1964) have formed a basis for development of complex use and water-resource protection schemes of the country and its regions.

Among the accomplished works on the regional groundwater discharge assessment and mapping, it is necessary to name groundwater discharge maps of the former Soviet Union territory in 1:2.500.000 scale (Karta podzemnogo stoka territorii SSSR, 1974), groundwater discharge map of Central and the Eastern Europe of 1:1.500.000 scale (Karta podzemnogo stoka Centralnoi i Vostochnoi Evropy, 1983) and recently edited hydrogeological conditions and groundwater discharge map of the Globe of 1:10.000.000 scale (World map of Hydrogeological Conditions and Ground Water Flow, 1999). The last two maps were created and edited by the international expert group under the auspices and at direct participation of the Russian experts under the frame of the UNESCO International Hydrological Program.

The fundamental difference of all specified groundwater discharge maps (and groundwater discharge maps of particular Russian artesian water basins similar in matter to the first ones) and the previously published hydrogeological maps is that these maps show regional quantitative features of natural groundwater resources (l/s square km) and their role in the general water resources and water balance (in percentage from an atmospheric precipitation and a long-term average annual river runoff) for the first time.

Groundwater discharge maps solve the following practical problems connected with complex use and protection of water resources. They determine natural fresh groundwater resources, which aids estimation and prediction of their usage prospects; they determine groundwater recharge value by regional estimations of their sustained resources; they determine the size of the underground component of the river runoff (being the steadiest part of surface water resources); and they determine the groundwater discharge value as the water balance element while planning the perspective of the complex use of water resources and their protection.

The groundwater discharge map of the globe mentioned above allows quantitative characterizing of the groundwater discharge in the seas and oceans, and helps to define the role of underground waters in world water balance.

Regional estimations of the groundwater discharge and natural groundwater resources are accomplished in single large artesian basins of the former Soviet Union territory (Vsevolozhskii V.A., 1983, Dzhamalov R.G., 1973, Zektser I.S., 1968, Lebedeva N.A., 1972, Shestopalov V.M., 1981).

The Regional Assessment and Mapping of Fresh Groundwater Protection from Anthropogenic Contamination

In recent decades, the progressing pollution of fresh groundwater often covering considerable territories is noted in many regions of the world. Overwhelmingly, this pollution is a direct consequence of general environmental contamination. Practically any kind of economic activity, such as exploitation of mineral deposits, application of fertilizers into the soil, hydraulic and construction engineering, deforestation, etc., inevitably affect the groundwater quality and often causes their pollution. Toxic waste disposal into deep aquifers also produce great damage to groundwater.

Groundwater is polluted by sulphates, chlorides, nitrogen compounds, mineral oil, phenols, and iron compounds; heavy metals whose content exceeds their threshold limit by values ten, or even one hundred times as large on particular sites. For example, more than 6.000 sites of groundwater pollution are detected on Russian territory (Informacionnyi byulleten, 2006) 40% of which are connected with the industrial plants activity, 13% - with activity of the agricultural enterprises, 12% of the polluted sites are connected with sewage and municipal services wastes. The majority of pollution sites (about 70%) are detected in the phreatic aquifers, which are not used as sources for public drinking water. The contaminated aquifer areas in certain cases reach tens of hundreds of square kilometers. Such pollution is presented in Dagestan Republic, the Perm region, the Novosibirsk region, Khabarovsk region, Tatarstan Republic, etc.

Groundwater contamination by mineral oil in areas of oil refinery factories and fuel and lubricant storage is the most common. However oil contamination of the environment, including groundwater, occurs not only in oil extracting and oil refining areas, but also in oil storages and oil pipelines areas. Thus, according to the American

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experts, about 50% of oil storages in the USA have leaks. Considerable leaks in the context of groundwater pollution occur almost in all petrol filling stations.

Various waste sites are the source of long-term groundwater contamination. We can mention, as an example, that Germany has about 40 thousand waste sites. 38 thousand dumps are registered in Russia. Mining industry alone has accumulated over 45 billion tons of waste. About 250 dumps exist in Moscow.

All aforesaid, and numerous available examples of groundwater pollution proclaim that it often appears as regional contamination. It poses a hazard and limits the possibilities and, above all, prospects of common groundwater usage for drinking water supply. Also, regional groundwater pollution is often caused by acid rains.

Fresh groundwater, the basic source of domestic water supply, is constantly in danger of existing and possible pollution. Thus, regional estimation and mapping of groundwater protection are of great practical importance. Groundwater protection is understood to be the property of the natural system, which maintains groundwater structure and quality that complies with requirements of their common use for the predicted period. The opposite concept is widely applied in the countries of Europe and America, where the groundwater vulnerability is taken into consideration. It is clear that the more groundwater protection, the less its vulnerability to pollution is, and vise-versa.

The concept is based on the assumption that the geological environment can provide some degree of groundwater protection from natural and anthropogenic impact. French hydrogeologist Z. Margat (Margat J. 1968) introduced the term "groundwater vulnerability related to contamination" in the late sixties. The first weather aquifer vulnerability map in relation to pollution (1:1.000.000 scale) was published in France (Albinet M. and Margat J. 1970).

The assessment of groundwater vulnerability to pollution is essentially a hydrogeological and geoenvironmental substantiation of protection measures in various natural and anthropogenic conditions. The experience of some countries such as Russia, the USA, Germany, Italy, etc., shows that it is possible to carry out a regional assessment and mapping of natural vulnerability of the aquifers used for water supply and irrigation. This assessment is usually based on the analysis and processing of all available hydrogeological data: first the data characterizing protective properties of an aeration zone.

The first assessment is territory valuation, which determines the impact level of various natural and anthropogenic factors on aquifer vulnerability. This compares various territory parts in terms of groundwater protection from pollution; to calculate time (speed) of certain pollutant penetration into the aquifer, taking into account natural properties of water, containing and overlying rocks, and pollutant migrational properties.

It is also possible to utilize two other methods: first, to estimate and chart resistant properties or groundwater vulnerability of any territory without certain pollutant characteristics and properties. Second, one assesses and maps natural, system-resistant properties, with reference to a certain kind of pollution.

The critical analysis of existing estimation and mapping methods of the groundwater protection, including the rather popular "Drastik-index" method, is given in the work of Aller L., and Bennet T. Aller L., Bennet T., Lehr J.H., Petty R.J., and Hachett G. (1987). One of the founders of the Russian groundwater protection assessment technique from pollution is Goldberg (Goldberg V.M., 1987, Goldberg V.M., Gazda S., 1984). He has offered a severity estimation of the impact of various natural factors on groundwater vulnerability. Development of the quantitative estimation technique concerning penetration speed or time of certain pollutant from the surface to the groundwater level was carried out in the works of Belousova A.P., Pitevaya K.E, Zektser I.S., Pashkovsky I.S., Pozdnjakova I., Lekhov M.V., Mironenko V.A., Rumynina V.G., Rogachevsky L.M., Karimova O.A. and other Russian experts.

Currently, maps of groundwater vulnerability to various scaled pollution are being made. It is necessary to note among them, the published maps of Flanders (Western Belgium), Poland, Lower Saxony, Sicily, Taiwan, California and other regions of the world, as well as a groundwater protection map of the USA, made with the use of Drastik-index technique.

It should be highlighted that, in practice, the most important is the regional estimation and mapping of the time during which the pollutant (or polluted flow, infiltrated from a surface) reaches the level. Calculations of time of pollutant penetration from the earth's surface to the groundwater level, in respect to the basic natural filters, are often carried out with the use of modern computer programs.

The degree of influence degree of the basic natural factors on groundwater vulnerability is different. Thus, for the nonartesian waters, the major factors determining the possibility of pollutant penetration into the groundwater from the earth surface are the thickness, structure, and sorption capacity of aeration zone rocks. For artesian water, these factors are the related pressure levels of the estimated and overlying nonartesian (i.e. potentially subjected to pollution) aquifers, and filtration properties of the aquiclude that separates them. Therefore, regional vulnerability assessment and mapping should be carried out apart from the basic aquifers whose waters are being used now or will be used in the long-term for water supply or irrigation. Thereby, besides quantitative characteristics, hydrogeological conditions of estimated territories, and the major conditions determining natural groundwater protection from pollution are reflected in the vulnerability maps (Belousova A.P., 2005, Belousova A.P., Galaktionova O.V., 1994, Zektser I.S., 2001, Zektser I.S., Belousova A., Dudov V., 1995).

The influence of major factors on groundwater protection in disturbed conditions compared to the natural or prevailing conditions can considerably change. For example, the intensification of groundwater withdrawal from nonartesian aquifers lead to an increase in groundwater cover thickness (aeration zone expansion) that changes (and in many cases improves) their protection from pollution from an earth surface.

Intensification of water withdrawal from confined aquifers occur in another way. For example, if the water flowing from the surface into potentially polluted groundwater is practically absent in certain natural conditions, relation levels of the confined and overlying nonartesian aquifer can change under operation conditions at the estimated decrease of aquifer water-pressure. That will considerably increase the danger of aquifer pollution and, can even lead to its transformation from the resistant to nonresistant aquifer.

Results of the quantitative assessment and mapping of groundwater vulnerability to pollution can be used for determining the groundwater use and protection strategy in various natural vulnerability areas. They can be used for substantiating of planning, including large industrial and agricultural projects with dangerous waste and sewage placing and development. The results help to substantiate the choice of location for waste accumulation and storage, and to find hydrological substantiation for various water protective actions.

One of the major practical results of protection assessment and mapping is the possibility to compare various territories, in regards to groundwater protection from pollution, and to determine what territory is better protected from pollution, where the biggest danger of pollution exists within water intakes that maintain groundwater for water supplies, and where water protection measures are necessary.

Groundwater vulnerability assessment and mapping should be the policy and strategy component of certain regions' groundwater use and protection. These works should be closely coordinated with the general, current, and long-term plan of environmental protection.

The Role of Groundwater in the Total Water Resources and Water Balance of Particular Regions, Including Coastal Zones of Seas and Oceans

Regional quantitative assessment of groundwater discharge into the rivers and seas determines the groundwater role in the total water resources and water balance of particular regions. This assessment has important practical value while drawing up the regional schemes of water resources complex use and protection, because it compares groundwater and surface water resources and determines prospects of their use on a quantitative basis.

Groundwater discharge coefficient values and groundwater river recharge coefficient values are used for the estimation. Groundwater discharge coefficient is a ratio (usually expressed in percentage) of the general groundwater discharge expressed in mm/year, to the atmospheric precipitation. Groundwater river recharge coefficient is the ratio of groundwater inflow to the river (usually in percentage) to the general river flow for the same period.

The long-term research accomplished in Russia, plus accumulated experience of the international works executed within the frame of the International Hydrological UNESCO Program, on a problem of groundwater discharge studying and mapping, have established the basic regularities of groundwater discharge coefficient value distribution, as well as groundwater river recharge coefficient value distribution in various natural, climatic, and hydrogeological conditions. Among these works it is necessary to name the international project "The Role of groundwater in a hydrological cycle and continental water balance", executed under the direction of the Soviet experts according to the International Hydrological Program of UNESCO (Zektser I.S., Dzhamalov R.G., 1988), maps of groundwater discharge on territory of the former USSR of 1:5.000.000 scale (Karta podzemnogo stoka SSSR v procentah ot obshego rechnogo stoka i koefficientov podzemnogo stoka v procentah ot osadkov, 1964, Karta podzemnogo stoka SSSR, 1964), and of 1:2.500.000 scale (Karta podzemnogo stoka territorii SSSR, 1974), a map of groundwater discharge in Central and Eastern Europe, and the corresponding monograph Karta podzemnogo stoka Centralnoi i Vostochnoi Evropy, 1983, Podzemnyi stok Centralnoi i Vostochnoi Evropy, 1982). It is reasonable to note a groundwater discharge map of California (Zektser, I.S., 2000), and also a map of the World hydrogeological conditions and groundwater discharge of 1:10.000.000 scale (World Map of Hydrogeological Conditions and Ground Water Flow 1:10.000.000 scale, edited by UNESCO, 1999).

The basic features of groundwater discharge coefficient distribution, showing what part of atmospheric precipitation goes on the groundwater rivers recharge, are determined by the complex influence of natural factors, the most important of which are atmospheric precipitation and evaporation ratio, and structure and thickness of the aeration zone rocks.

In the territory of the former Soviet Union groundwater discharge coefficient values are about 10 % on average, changing from 1% to less than 50%.

Presence of high groundwater discharge coefficient values (more than 100%) testifies to the essential participation of, not only, atmospheric precipitation infiltration but of other sources of these values and their formation in a groundwater recharge, including losses of river runoff and groundwater recharge by means of the intensive irrigation that exceeds water duty.

Latitudinal zonality is the general trend for even territory. Latitudinal zonality is a groundwater discharge coefficient decrease from the northwest to the southeast from 10-20% in an over-watering zone to 1% and less in steppe and semiarid areas. In a number of areas this trend is "violated" by anomalies, mainly by the increase of groundwater discharge coefficient values.

First of all, Latitudinal zonality is observed on uplands, which is caused by an abundance of atmospheric precipitation and improvement of their infiltration conditions, for example: the Valdai, Sredne-Ruskaya, Privolzhsky uplands, the Yenisei ridge, the North Baikal uplands, etc.

Along with the terrain elevation increases in mountain areas, groundwater discharge coefficients reach certain limits simultaneously with the atmospheric precipitation. Therefore, they increase in Carpathians from 5 to 10-15%, in Ural Mountains from 10 to 20-40%, on Altai from 5-10 to 15-20%. Groundwater discharge coefficients increase appears very distinctly on the Caucasus and in the mountains of Central Asia. Its value comes up to 25-35%.

In karst development areas, groundwater discharge coefficient values are also high. They increase to 30-40% and more on the Silurian plateau, on Onego-Severo-Dvinskom interstream area, the Kulojsky plateau, and Timan).

The permafrost role in groundwater discharge coefficients distribution is very evident. On huge spaces of Siberia and the northeast of Russia where precipitation values are 300-400, reaching 500-600 mm in some places, groundwater discharge coefficients are rather insignificant, about 5%. Only in the south of Siberia (Northern Pribaikalye and outskirts of the Verkhoyansk ridge) where the permafrost develops insular character and an annual amount of precipitation increases up to 800 mm, groundwater discharge coefficients reach 15-20% and more.

It is impotant to note that the groundwater rivers recharge coefficient values show the groundwater discharge fraction in the general river runoff, and thus allow the estimation of the ratio of groundwater to surface water resources in many humid zone areas.

On average, the groundwater rivers recharge coefficient is 24%, changing from 5-10% in areas with rather small zone thicknesses of the intensive water exchange, coarse topography, and favorable conditions of surface discharge formation, and 40-50% and more in the areas formed by rather water-abundant rocks and intensively drained rivers.

Due to basic, natural, and climatic factors, geographic zonality influences the distribution of groundwater rivers recharge coefficient values on the territories of Central and Eastern Europe. In the north (the Karelo-Kola region, Pechora river basin, Barentsevo and White seas basins, and northern part of the Baltic), groundwater rivers recharge coefficients change from 10 to 30%. Here, favorable conditions for surface and overland runoff formation are created, because the area topography is rather coarse and groundwater occurs superficially.

In the central part of the Russian platform groundwater rivers recharge coefficient reach 40-50%. In this zone, favorable conditions like a thicker zone of intensive water exchange and good drainage condition cause groundwater river recharge. South of this zone, groundwater participation in river runoff formation strongly decreases and groundwater river recharge coefficients decrease to 10-15% and less. In arid zones where evaporation predominates in groundwater balance, groundwater inflow to the rivers is practically absent [Podzemnyi stok na territorii SSSR, 1966, Podzemnyi stok Centralnoi i Vostochnoi Evropy, 1982).

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Mountain areas are characterized by higher groundwater rivers recharge coefficient values than the lowlands. The tribute of groundwater inflow to the rivers reaches 70-80% within the mountainous areas of Central and the Eastern Europe. Sometimes it comes up to 100%. This is caused by good drainage of the water-containing rocks, the increased quantity of atmospheric precipitation, and favorable conditions of their infiltration, such as increased fracturing rocks, large detrital deposits development, karst, etc. Pevailing groundwater river recharge coefficient values for the majority of mountain rivers are 40-60%, with considerable fluctuations of their extreme values. For example, the groundwater inflow tribute to the mountain rivers changes from 2-5 to 70-75%.within the Big Caucasus.

During the complex water-resource-usage problem, solving the analysis of groundwater discharge and the general river discharge ratio has gained considerable practical importance. The analysis is also important when water economic balances of separate regions are worked out and when the groundwater exploitation impact on a river runoff is estimated.

Being a component of complex hydrologo-hydrogeological problem of land and sea groundwater exchange studying, regional researches of groundwater discharge into the seas and oceans were extensively developed during the last decades (Zektser I.S., Dzhamalov R.G., Mesheteli A.V., 1984).

In recent years, practice demands on “the internal seas problem” became the main reason for stating and developing researches goal, focused on groundwater discharge into the seas. The core of this problem lies in considerable water level changes, caused by both natural factors and intensive economic activities in drainage areas, in many internal seas (like the Caspian and Aral) and large lakes. Concerning the internal sea problem, the following object was formulated: to study modern and prospective water and salt balances of these water basins and, hence, to assess the groundwater role in the development of these balances. Thus, groundwater influence should be investigated, not only on water basin water and salt balances, but also the influence on its features of hydrochemical, temperature and hydrobiological modes. Considerable experience of quantitative estimation researches of the groundwater discharge into internal and shelf seas and large lakes has been collected so far.

The primary goal of this researches is to study features and regularities of the process of water and salt exchange of a water reservoir with land, and also to substantiate the forecast of changes towater balance underground components under the influence of increasing economic activities.

It is important to note that many groundwater intakes are located at the seacoasts, and their conditions are specified, in many respects, by the character of groundwater and seawater interaction. In such conditions, research of sea and groundwater interaction in coastal areas is conducted to determine the optimal water intake yield in maintaining coastal groundwater. As a result of such water intakes, there is intensive exploitation of water exchange in ‘sea-groundwater’ system changes. The important problem facing hydrogeologists is to determine the position of discontinuous surfaces like “fresh groundwater-salty sea water” and, hence, to forecast the water quality of groundwater intakes located at sea coasts.

Groundwater discharge into the seas is the important indicator of groundwater resources. In seaside areas, the lack of high-quality fresh water can be considerably reduced or even covered completely by means of groundwater use, which, as of now, flows pointlessly into the sea.

In some countries, there already exists the positive use of a large submarine spring waters that discharges into the sea near the coast, as well as te exploitation of wells, which are drilled on a shelf and allowed to use fresh groundwater for water supply of seaside settlements.

During recent years, methodological bases of regional assessment of groundwater discharge into the seas, oceans and large lakes are developed. They are particularly considered in the special literature (Zektser I.S., Dzhamalov R.G., Mesheteli A.V., 1984, Zektser I.S., Dzhamalov R.G., 1989). For the first time in world practice, the application of the developed methods has executed an estimation of groundwater discharge directly into the ocean from all continents of the Earth. They characterized, on a quantitative basis, the groundwater role in the water and salt balance of coastal zones. As a result, specific features have been received of groundwater discharge directly into the seas and oceans, passing a river system. These features were presented in the form of groundwater unloading from one square km of bailing area, and in the form of the linear modulus (groundwater inflow on one km of coastal line). They also were presented as combined values of groundwater discharge into the seas and large lakes. The dissolved salt flow into the seas with groundwater discharge has also been estimated. The main results of these surveys are presented in the works of (Zektser Igor S., Dzhamalov Roald G., 2007, World map of Hydrogeological Conditions and Ground Water Flow 1999).

Assessment and Study of Transboundary Groundwater Aquifers for the Prospective Use of Water Supply and Irrigation of Adjoining Territories

The formation of conditions and prospective usage of transboundary fresh grandwater aquifers appears to be a rather new section of regional hydrogeology.

As is known, in recent years, the problem of transboundary water use has become rather urgent for many countries. It refers, though not exclusively, to interstate borders where questions of boundary or transboundary (crossing borders) river-use, in many cases, are regulated by special international agreements. For example, we can name agreements between Russia and China about Amur river water use, the agreement between the governments of Russia and Estonia about cooperation in the field of transboundary water protection and rational use, and other international arrangements. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes adopted in Helsinki in 1992 is of great importance. It stressed the need for agreeing on a united approach for interstate protection and transboundary water usage. Transboundary waters include surface and groundwater.

The problem of transboundary water use regulation is rather pressing inside particular countries, such as the USA, Australia, Russia, India and others. In such countries, administrative regions (states, districts, federal divisions) have constitutional independence, and they settle natural-resource-use problems almost independently, coordinating the key basic nomothetic documents only with neighbours or federal bodies. For example, in Australia, in each state, special commissions on water resources of the state are available. They give out permissions for water use (including drilling of artesian wells), research and design work organisation, determine limits of acceptable water withdrawal for different state’s needs, and carry out the control over water quality and pollution level.

It is necessary to note that problems of transboundary river use and protection are fixed slightly easier than transboundary groundwater aquifer use. This is because the majority of the countries have a good survey network over the river water expense and quality, and a number of countries have specially equipped hydrometric stations on their borders, which constantly measure the expense and structure of river water. In these cases, the quantity and quality of water that should be kept for the neighbouring states are regulated and controlled according to existing international agreements.

Transboundary groundwater aquifers study and usage is much more difficult. Today, the experience of the regional transboundary aquifers resource and quality assessment, including, first of all, the prospective estimation of their possible usage and permissible limits assessment, is extremely limited, in spite of the fact that such transboundary aquifers exist almost in all countries (except for the insular states).

Considering the importance of the problem and, according to the objects of the International Hydrological Program, a special workshop was organised in UNESCO. The aim of the workshop is to consider and the analyse the current situation of transboundary groundwater studying and use.

We will consider the primary goals of regional researches of transboundary aquifers which have their own significant importance, without entering into the legal and economic aspects of transboundary groundwater use. After the disintegration of the Soviet Union, the problem of transboundary aquifers in Russia became rather urgent, as it has land boundaries with 13 sovereign countries. Today it is necessary to develop the scientifically-proved assessment principles of groundwater resources management and use in border regions of Russia with obligatory observance of nature protection requirements. These principles should include both working out of the region, constantly operating hydrodynamic models of interconnected aquifers system, and the assessment of groundwater pollution at its current and perspective use.

At present it is possible to mark the following specific objects of transboundary aquifers studying and use:

- Quantitative estimation of boundary and transboundary aquifers' natural and sustained resources: regional estimations methodology is based on hydrodynamic calculations, including regional models of groundwater flow rates and possible aquifers productivity, including large groundwater intakes;
- Chemical, biological and radioactive structure: determine acceptable changes of level specification of groundwater;
- Assessment of the vulnerability of fresh transboundary groundwater aquifers to technogenic pollution originating from the earth surface;
- Scientific and methodological substantiation of interstate agreements on acceptable limits of groundwater aquifers use, including geoenvironmental aspects, acceptable levels of groundwater withdrawal, danger of aquifers pollution and depletion;
- Determining joint interstate monitoring of transboundary groundwater aquifers use and protection.

The main principles of the international agreements in the field of environmental management and environmental protection include the state's sovereignty on natural resources of its territory, inadmissibility of ecological well-being of one state at the expense of ecological harm to another, the decision of environmental and judicial disputes by peace means, etc.

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