Investigation of transboundary aquifers in Russia: modern state and main tasks

Igor S. Zektser, Prof.[1]

(1) Water Problems Institute, Russian Academy of Sciences, Moscow, 119333, Gubkina St., 3, email: zektser@aqua.laser.ru

ABSTRACT

Transboundary problems of groundwater development are rather acute for Russia as it has land boundaries with 13 countries. The main research line concerning this problem is to develop principles and criteria of acceptable groundwater withdrawal by neighboring countries with compliance of environmental limitations. This includes groundwater protection from depletion and contamination, development of constant groundwater deposit models spread in border regions of neighboring countries in order to determine groundwater balance elements of certain hydrodynamic flows, their internal interaction and interaction with surface water. Estimation of potential groundwater shared use based on large scaled assessment and mapping of its sustained yield with regard to groundwater protection from contamination is of importance either.

Determination of prospects for groundwater use and withdrawal management is always connected with the problems of exploitation restrictions in accordance with different criteria. The latter may be both of inside and outside types. Among inside criteria are limitations of hydrogeological and hydrodynamical operation conditions, such as groundwater recharge rate, tolerance dynamic level lowering throughout estimated period, risk of non-standard groundwater drawing up to a water intake, and others. The outside criteria that can restrict the groundwater use are related to possible impacts of a planned water extraction upon different environmental components including river runoff, suppression or death of vegetation due to excessive lowering of shallow groundwater level in the upper unconfined aquifer; activization of karst and suffusion processes; earth surface subsidence, etc.

The main tasks of hydrogeological investigations are the following:

- Determination of admissible limits of groundwater extraction in each of boundary countries in order to prevent water reserves depletion in neighboring countries.
- Regional evaluation of natural groundwater resources of an exploited aquifer.
- Assessment of a groundwater pollution hazard in trans-boundary aquifers and development of joint recommendations preventing such pollution.

Specific examples of transboundary groundwater use perspective assessment in particular adjacent zone regions of Russia are presented.

Key words: transboundary aquifers, groundwater discharge, natural resources, vulnerability, core of depression.

1. INTRODUCTION

In recent years the problem of transboundary waters use has become rather actual in many countries. It concerns not only the interstate boundaries where the use of marginal or transboundary rivers (rivers that cross boundaries) in many cases is regulated by special international agreements. Also the problem of transboundary water use regulation is rather acute inside some countries (e.g. USA, Australia, Russia, India and others), where particular administrative regions (states, regions, federal divisions) have a constitutional independence and solve many problems of natural resources use independently, coordinating basic legislative acts only with neighboring countries or federal organs.

In Russia the principle of the superiority of international right to the state right in the field of the environmental protection and natural resources use is legislated by the Federal Law (Zektser, 2000)

The basic principles of international agreements in the field of natural resources use and environmental protection include sovereignty of a country over the natural resources of its territory;

impossibility of reaching safe environmental situation in one country while the environment of another country is being damaged; and settling of environmental and legal disputes by peaceful means, etc.

Without mentioning the legal and juridical problems of natural resources use in boundary regions, we would like to note that presently the cost of liquidation of adverse consequences from human activity's impacts on the environment (for example, pollution of water resources) is known to considerably exceed the cost of predictive and warning measures.

It should be noted that the problem of assessment of possible and perspective groundwater use in transboundary areas is of great importance for many countries in the world. Moreover, this problem is one of the most weakly studied in hydrology and hydrogeology. The specialists have to answer several important questions, such as: what is the mutual hydrodynamic influence of existed water intakes on groundwater; how much water can be withdrawn from transboundary aquifer by each country without depletion of groundwater resources; is there a danger of aquifer contamination; what are the perspectives of groundwater use in boundary areas of each country and etc. The careful analysis of hydrogeologic and hydrodynamic conditions in boundary zone by specialists from both sides is necessary for solving these problems.

2. OBJECTIVES

Basic problems concerning transboundary aquifers study and use are often tightly connected with each other. These problems are the following (Zektser, 2007):

(1) Quantitative assessment of natural and exploitable groundwater resources of boundary and transboundary aquifers. The method of such regional estimation is developed well enough. It is based chiefly on hydrodynamic calculations, including regional models of groundwater discharges and possible productivity of aquifers and large groundwater well fields;

(2) Determination of chemical, biological and radionuclide compositions of groundwater and an allowable level of its changes;

(3) Estimation of fresh groundwater vulnerability in transboundary aquifers to anthropogenic contamination penetrating from the earth's surface;

(4) Scientific and methodical substantiation of inter-country agreements on allowable limits of groundwater use from transboundary aquifers, including, geoenvironmental aspects, allowable levels of groundwater extraction, a risk of aquifer contamination and depletion;

(5) Development of joint interstate monitoring of transboundary aquifers groundwater use and its protection.

At present the main problem of hydrogeologic investigations in Russia is to develop scientific bases of rational use and forecasting of groundwater resources from transboundary aquifers. The main tasks concerning these problems are the following: to analyze the peculiarities of fresh groundwater formation and distribution in boundary regions of Russia; to develop methodologies for forecasting the rational use of groundwater from transboundary aquifers; to develop principles and criteria of permissible joint groundwater withdrawal from transboundary aquifers considering groundwater protection from contamination and depletion; to develop constant-working mathematical models of groundwater deposits distributed in boundary areas of neighboring states, which aim to determine conditions and values of hydrodynamic flows recharge and discharge; to approbate the models on specific examples in boundary areas between Russia and neighboring countries of the former USSR.

The main tasks of hydrogeological investigations are the following:

- Determination of admissible limits of groundwater extraction in each of boundary countries in order to prevent water resources depletion in neighboring countries.
- Regional estimation of natural groundwater resources of an exploited aquifer.
- Assessment of a groundwater pollution hazard in transboundary aquifers and development of joint recommendations preventing such pollution.

Below the basic tasks of hydrogeological investigations in boundary regions are briefly considered.

3. RESULTS AND DISSCUSSION

3.1. Determination of admissible limits of groundwater extraction in each of boundary countries in order to prevent water reserves depletion in neighboring countries.

In most cases the given matter concerns usually two neighboring countries exploiting the same aquifer for water supply or irrigation. Here, the most important task is to determine the position (sizes) of the depression cone at the current stage of water extraction and at the predicted stage of water withdrawal, taking into account an admissible (by hydrogeological criteria and criteria of environmental protection) level decrease in the aquifer for 25 or 50 years of exploitation.

3.2. Regional estimation of natural groundwater resources of an exploited aquifer

Natural resources characterize the part of water which is continuously being renewed during general water circulation at the expense of infiltrated precipitation, absorbed river runoff and water seepage from other aquifers. Average multi-year groundwater recharge excluding evaporation is equal to a groundwater flow value. Therefore in regional evaluations the natural groundwater resources are often expressed in average annual or minimal groundwater flow modulus. Natural groundwater resources represent the upper limit which determines the productivity of continuously functioning water well fields. The productivity is provided by their natural recharge during an unlimited exploitation period (except water well fields the yields of which are formed from additional reserves involved during exploitation). The methods for regional estimation of average multi-year values of natural groundwater resources are sufficiently well developed and described. These methods are the following: genetic separation of hydrographs of rivers draining groundwater from basic aquifers for a multi-year period; hydrodynamic calculations of flow rates, including modeling; analysis of low water runoff of rivers draining groundwater; water balance and calculation of infiltration recharge of groundwater, etc. Each of these methods has certain advantages and disadvantages. Possibility to use a particular method depends on geological and hydrogeological conditions of a studied territory and availability of reliable factual data. However, all above-mentioned methods have certain advantage. Using these methods it is possible to carry out regional estimation of natural groundwater resources by means of analysis. Also available information can be obtained without conducting special expensive drilling and experimental and filtration works. To determine the prospects of groundwater use, it is important to estimate not only the average annual, but also seasonal (especially minimal) values of groundwater renewal. This can be done by analyzing the multi-year observations of groundwater level regime.

3.3. Assessment of a hazard of groundwater pollution in transboundary aquifers and development of joint recommendations preventing such pollution

Numerous facts show that groundwater pollution is often of regional character. It restricts the possibility and prospects of practical use of fresh groundwater including fresh groundwater in boundary regions. Therefore, the regional assessment and mapping of groundwater protection against pollution in transboundary aquifers become of a great importance in conditions of existing and possible hazards of pollution to groundwater as a source of domestic and drinking water supply. Under

"groundwater protection" one should understand the environmental possibility to preserve the composition and quality of groundwater during a predicted period (25 or 50 years), meeting the appropriate requirements of practical water use. The concept opposite to the given one is "groundwater vulnerability" to pollution. This term is widely used in the foreign literature. The higher (better) the protection of groundwater is, the lower is its vulnerability and vice versa.

Two different approaches can be distinguished. The first one is assessment and mapping of groundwater vulnerability on any territory without taking into account the characteristics and properties of particular pollutants. The second one is assessment and mapping of a natural system applied to a particular type of pollution.

The majority of methodologies are based either on qualitative or quantitative analyses of different factors affecting groundwater vulnerability. Usually a degree to which unconfined groundwater or groundwater in the upper confined aquifer is protected is being assessed.

Results of quantitative assessment and mapping of groundwater vulnerability to pollution can be used in the following concepts: development of a strategy for groundwater use and protection in areas with different natural vulnerability; substantiation of plans for location and development of large industrial and agricultural objects with hazardous liquid and hard wastes; hydrogeological substantiation of different water-protective measures; selection of places for accumulation and storage of wastes.

One of the most important practical results of assessment and mapping of groundwater protection is the possibility to compare different territories concerning groundwater protection against pollution and decide which territory is protected better. Assessment and mapping allows to find out where a high risk of pollution of water well fields exploiting groundwater for water supply exists, as well as to learn where water protective measures are primarily necessary.

Geofiltrational models of Russian and Estonian, and Russian and Ukrainian border regions have been developed in recent years in Russia to determine the prospects of transboundary aquifers use. Modelling results are shortly stated below.

3.4. Russian and Estonian border

Russian and Estonian hydrogeologists teamwork resulted in integrated Russian-Estonian geofiltrational model of lomonosovskiy-voronkovskiy aquifer. The model is based on the analysis of available hydro-geological information on the Estonian Republic territories, the Leningrad and Pskov regions of Russia. Water containing formations of this aquifer are presented by quartz sandstones with interbedded clays with total thickness of 30 meters. The thick stratum of loptovskiy clays serves as their upper aquiclude and clays of upper Proterozoic appear as their bottom. This aquifer is subartesian one with pressure value about 100 m. Water levels in wells are established at depths of 15-45 m. The aquifer is maintained in border regions of Russia and Estonia. Three possible variants of development of hydrodynamic situation in Russian and Estonian border area have been considered in the regional model: They are the following: 1) the new water intake in Ivangorod with productivity of 3000 m3 per day is added to the already operating water intakes with existing productivity; 2) water withdrawal from all water intakes on the Russian territory, including the new one in Ivangorod, has increased twice, and Estonian water intakes yields remain constant; 3) Estonian water intakes yields are decreasing twice. As a result the groundwater overflow through Russian-Estonian border under the influence of water withdrawal has been determined to be much lower than their natural discharge through it. Even double decrease in water withdrawal from this aquifer on the Estonian territory will not change the current hydrodynamic conditions. Only the high increase in water intake on Russian territories can change the hydrodynamic situation up to the complete inversion of the natural flow.

Researches of Russian and Estonian transboundary aquifers were the first and almost the only joint work of experts from neighboring countries concerning transboundary groundwater studying. These researches can be an example of the international cooperation on this challenge (Mironova, Molskii, Rumynin, 2006).

3.5. Russian and Ukrainian border

The integrated base of cartographic and factual data for the general mathematical model of transboundary aquifers of Dneprovo-Donetsk artesian basin is created. The model covers the territory of 248×276 km, a grid step is 1 km. Northern part of model includes the Belgorod region of Russia, southern part comprises the Kharkov region of Ukraine. 4 aquifers and three relatively impermeable layers are considered vertically. The basic regional water intake is coincided with the second one which consists of maastriht-turonskiy and alb-senomanskiy aquifers.

On model living conditions the specifications of existence of regional hydrodynamic flow for undisturbed filtration regime have been reproduced. Hydro- and pezoizogips maps for 4 aquifers and a water exchange map between them have been constructed as well. Also the data on balance components have been obtained. Besides, graphic representation of groundwater flows for simulated aquifers concerning state borer is received.

To reproduce the disturbed filtration conditions all existing water intakes of the Belgorod region for the periods of 1970, 1980 and 1990 have been set with prolongation of ten-percentage increase in water withdrawal till 2009.

Maps of levels decrease in exploited aquifers and also tables of certain hydrodynamic balance components on calculated time steps are received.

The analysis of structure of groundwater resistance indicators and their quality for transboundary aquifers of the Dnepr and Don River basins showed that the Dneprovsko-Donetskiy basin is characterized by an high resistance indicator, and the Donetsk basin has extremely low groundwater resistance indicator to anthropogenic impact (Belousova, 2005).

4. CONCLUSIONS

In conclusion, it should be noted that transboundary problems of groundwater development are rather acute for Russia as it has land boundaries with 13 countries. Basic tasks concerning solution of these problems at the current stage are the following: - development of principles and criteria for admissible groundwater extraction by the neighboring countries regarding nature protection restrictions, including groundwater protection against depletion and pollution; - development of constantly functioning models of groundwater fields in boundary regions of neighboring countries in order to determine groundwater balance elements in particular hydrodynamic flows and their interaction with each other and with surface waters both in natural and anthropogenically disturbed conditions; - determination of prospects for joint use of groundwater on the basis of large-scaled assessment and mapping of groundwater safe yield taking into account its protection against pollution.

Acknowledgments

The author sincerely thanks the staff of Water Problems Institute, Russian Academy of Sciences: Polshkova I.N., Novoselova L.P. and Chetverikova A.V. for their assistance in conducting the research and preparing this article.

REFERENCES

A.P Belousova (2005): Resursy podzemnyh vod i ih zashishennost ot zagryazneniya v basseine reki Dnepr i otdelnyh *ego oblastyah: Rossiiskaya territoriya (Groundwater resources and their protection from pollution in the Dnieper River basin and its separate areas: the Russian territory)*. M: LEN AND, 168 pp.

A.V. Mironova, E. V. Molskii, V. G. Rumynin (2006): Transgranichnye problemy pri ekspluatacii podzemnyh vod v raione gosudarstvennoi granicy Rossiya-Estoniya (na primere Lomonosovsko-Voronkovskogo vodonosnogo gorizonta) (Transboundary problems of groundwater withdrawal in state border area of Russia and Estonia (the Lomonosov-Voronkovskiy aquifer as an example*)*. *Vodnye resursy*, 33(4): 423-432.

I.S. Zektser (2000): *Groundwater and the environment*. Levis Publishers, USA, 175 pp.

I.S. Zektser (2007): Osnovnye napravleniya issledovaniy transgranichnyh gorizontov pri opredelenii perspektiv ekspluotacii (Basic trends in transboundary groundwater investigation for determining of exploration prospects), *Izv. Vysshih uchebnih zavedeniy. Geologiya i razvedka*, 6: 64-67.