

Some Problems of Monitoring, Assessment and Management of Transboundary Aquifers

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Abstract

Phase I of the ISARM program, in which we defined 15 transboundary aquifers in Kazakhstan, comes to an end. Now we are able to offer some results and define problems of monitoring, assessment and management of transboundary aquifers, which will demand scientific decision regarding:

1. Scale of research.
2. Area of transboundary aquifers.
3. Risks of occurrence of transboundary problems.

An important element underlying the methods of monitoring, assessment and management of resources of transboundary aquifers is a typification of such problems.

Key words: transboundary aquifers; Republic of Kazakhstan; monitoring and assessment, transboundary groundwater problems

1. TRANSBOUNDARY AQUIFERS INVENTORY IN KAZAKHSTAN

Recently, study of transboundary groundwater has been widely developed in Kazakhstan since due to recommendations provided by ISARM regarding stage I of transboundary aquifers inventory (Puri & Aureli, 2005). The common aim of works was to identify transboundary problems that require organizational intergovernmental efforts for solution thereof.

Transboundary aquifers inventory was carried out on the basis of typification of some specific features offered by ISARM that include aquifer type, reservoir system, dominant hydraulic state, predominant groundwater flow direction, and boundary conditions.

Type of aquifer depends on the type of groundwater body permeability. Aquifers may be porous, fractured, and porous-fractured. Through the analysis the types of transboundary groundwater reservoirs in Kazakhstan it was found that type of transboundary aquifer indirectly predetermines the hazard of transboundary problem exposure.

Fractured transboundary aquifers in Kazakhstan are spread out in the mountainous area. The state border crosses watersheds, river beds, and mountain rivers. Recharge area normally coincides with the spread out of aquifer area. Hydrogeological features allow using only resources of these aquifers, normally, spring runoff. Due to low population density in this territory and thus, low intensity of groundwater use, transboundary problems are not likely to occur. Exceptions are carbon-bearing geological structures with a combined type of permeability that contain their waters in fractures and karsts. However the state border of Kazakhstan does not cross such structures.

Porous transboundary aquifers are spread out in the territory where the state border normally crosses plain terrains. In these areas, the transboundary aquifers more frequently form a uniform water-bearing system consisted of aquifers and aquitards. The main risks of transboundary problems are associated with such systems.

There are phreatic (the first from of the unconfined surface), semi-confined, and confined transboundary aquifers in terms of the dominant hydraulic state. Intensity of mass exchange is

crucial for confined aquifers. Deep-occurring confined waters are several thousand years old and require no pollution protection measures due to a low vulnerability thereof. It is obvious that measures are aimed at protection of recharge areas of such aquifers (the state, within the territory of which such areas are located, bears responsibility for such protection) will not influence the conditions of groundwater at near future in the area of their use.

Groundwater flow direction in relation to the state border determines referring of the recharge areas of the transboundary aquifer to the territory of this or that state, and possibility of pollution transfer by groundwater flow from a certain side.

Finally, these all taxonomic units of typification of transboundary aquifers are reflected in the schemes of boundary conditions of groundwater flows. Simplified pictures of transboundary groundwater systems from UNECE datasheet groundwater may be used as such schemes at a first approximation. They allow to visualize any possible risks of pollution and depletion of groundwater of transboundary aquifers and determine possible ways for assessment of such risks. In its turn, this allows to substantiate a type of monitoring and assessment of transboundary aquifers and define their development.

There are fifteen transboundary aquifers in Kazakhstan (Fig. 1), the land's state border of which is over 13000 km (Podolny *et al.*, 2008). Each of these transboundary aquifers has been assessed in terms of occurrence or possible occurrence of risks of transboundary interstate problems that require attention of relevant authorities aimed at mutual use and protection of groundwater resources of such aquifers. Now from this it is possible to bring some results and to define problems of monitoring, assessment and management of transboundary aquifers, which will demand scientific decision:

1. Problem of scale of researches.
2. Problem of area of transboundary aquifers.
3. Risks of occurrence of transboundary problems.

The typification of such problems is the important element underlying the basis of methods of monitoring, assessment and management of transboundary aquifers.



Fig. 1. Transboundary aquifers in Kazakhstan

1 - North-Kazakhstan; 2 - Preirtysh; 3 - Zaisan; 4 - Alakol; 5 - Zharkent; 6 - Tekes; 7 - Shu; 8 - North-Talas; 9 - South-Talas; 10 - Pretashkent; 11 - Syr-Darya; 12 - Amu-Darya; 13 - Precaspian; 14 - Syrt; 15 - South-Pred-Ural.

2. PROBLEM OF SCALE OF RESEARCHES

These transboundary aquifers have been allocated with reference to scale of mapping 1:10,000,000. It is well-known that possibility of display of units of hydro-geological stratification depends on mapping scale. Fifteen transboundary aquifers which have occurred in Kazakhstan correspond to quantity of transboundary hydrogeological regions of 3-4 orders which are, in effect, basins of groundwater. Though these basins are named "transboundary aquifers" or "systems of transboundary aquifers," in the specified scale it is possible to show aquiferous supercomplex (the hydrogeological body consisting from several aquifers, complexes and zones, separated from adjacent hydrogeological subdivisions by aquitards or local confining complexes) and aquiferous group (system of aquifers, complexes, zones, supercomplexes, that are characterized by independent conditions of water exchange). Designing of a network of monitoring of transboundary aquifers, even of the very first level - monitoring of the early prevention (UNECE, 2000), demands larger scale of mapping (1:500,000 and larger). Hydrogeological stratification should be constructed according to such scale, and it should be more fractional. It will demand more detailed description of transboundary aquifers; will separate layers in which points of observation network of monitoring should be defined. The main hydrogeological subdivisions mapped in scale 1:500000 and larger, are: an aquifer, a complex, a zone, which are allocated on the basis of the accepted hydrogeological criteria of hydrogeological stratification of a geological section:

- type of groundwater body permeability;
- value of groundwater body permeability;
- the content of gravitational water in geological bodies;
- spatial variability of groundwater body permeability and waterness.

At the type of groundwater body permeability groundwater bodies are divided into two groups: with porous and fractured (including karstic and fractured-karstic) permeability. This criterion is included at ISARM' typification of transboundary aquifers.

At value of permeability the groundwater bodies are differentiated into permeable bodies (aquifers) with hydraulic conductivity more than 1 m/day, poorly permeable bodies (poorly aquifers) with hydraulic conductivity from 1×10^{-4} to 1 m/day, and water-proof (aquitards) with hydraulic conductivity less 1×10^{-4} m/day.

At the content of gravitational water the geological bodies are divided into water-bearing bodies (containing gravitational water) and waterless.

At spatial variability of water permeability the hydrogeological bodies are divided into homogeneous and heterogeneous (value of hydraulic conductivity varies within several gradation).

Thus, aquifer (weak aquifer) is the water-bearing hydrogeological body homogeneous for type and value of permeability, and aquitard - water-proof hydrogeological body.

Aquiferous complex is the water-bearing hydrogeological body with porous heterogeneous permeability in which it is not possible to allocate separate aquifers and aquitards in mapping scale 1:500,000 or larger. In case of prevalence in complex poorly aquifers it is allocated as a poorly aquiferous complex, and at prevalence of aquitards - an aquitard complex.

Aquiferous zone (fractured aquifer) is water-bearing hydrogeological body with fractured permeability.

The assessment and management also should be constructed according to such stratification.

3. PROBLEM OF AREA OF TRANSBOUNDARY AQUIFERS

There is some uncertainty about the defining the area of transboundary aquifer. Resolution of UNGA (A/RES/63/124) defines "transboundary aquifer" and "transboundary aquifer system" as an aquifer or aquifer system, part of which are situated in different States (Stephan, M.R, *editor*, 2009). Thus, transboundary aquifer is defined as area equal of its existence on either side of the border. And for the confined aquifers this condition to the full is carried out, and groundwater abstraction of one of the countries leads to occurrence of transboundary problems. A good example is the groundwater abstraction of the Preirtysh transboundary (Kazakhstan-Russia) aquifer system, which is more than

400000 км². The system of these transboundary aquifers consists of Paleogene, Upper Cretaceous, and Lower Cretaceous aquifers. The Preirtysh transboundary aquifer is a part of a huge artesian basin of the West Siberian plate. Today Russia intensively uses these transboundary aquifers to supply water to large cities such as Novosibirsk, Barnaul, etc. According to the monitoring research carried out by the Committee of Geology of Russia, drawdown area caused by operation of large water intake facilities reached 50000 км² at a maximal drawdown of 35 m and covers the territory of Kazakhstan (Fig. 2). Drawdown of a groundwater level of these aquifers is fixed in observation wells of network of the State Groundwater Monitoring of Kazakhstan (Fig. 3).



Fig. 2. Fragment of The map of a status of groundwater of territory of the Russian Federation (as of 01.01.2007), with addition (Lygin, A.M., editor, 2007)

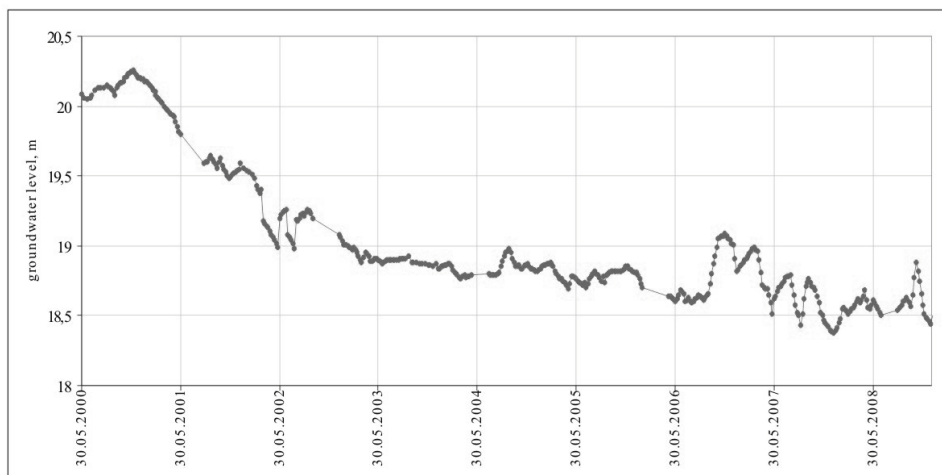


Fig. 3. Drawdown of groundwater level of Cretaceous aquifer' in the observation's well 38 in Kazakhstan

However, in the conditions of an unconfined aquifer which can have the big area and its existence area could coincide with the area of recharge, transboundary effects do not exist. For example, the aquifer of the Irtysh river valley (see fig. 2) has thickness near 50 meters and is about 600 square kilometers in Kazakhstan only. This vast aquifer lies in the system of the Priirtysh transboundary aquifer. Thus, sites of pollution of groundwater of this aquifer are not transboundary. Transboundary effects, according to calculations, can be shown on distance to several kilometers to border, and the area of possible interference does not exceed five square kilometers. It considerably reduces financial and other expenses for studying, monitoring, and assessment and, as a result, the management of such aquifers.

4. RISKS OF OCCURRENCE OF TRANSBOUNDARY PROBLEMS

The problems of exhaustion and pollution of transboundary aquifers not always are transboundary problems. First of all, all transboundary water problems related to groundwater resources may be divided into two groups. Arrangement of monitoring and assessment of transboundary groundwater and management of resources use within the groups differ dramatically.

Group 1. Transboundary river problems, associated with qualitative and quantitative condition of groundwater within the transboundary river basin.

The reason of such problems is related to the use of groundwater of aquifers fed by such a river, thus resulting in falling of river runoff, or contamination of groundwater in the catchment areas and infiltration of contaminated waters to the transboundary river thus resulting in impairment of quality of transboundary river waters delivered to the adjacent side.

We believe that such problems can be easily solved inside the state by implementing the methods of integrated water resources management into the water management system. They require close attention of relevant authorities and allocation of a certain budget for solution thereof. The major part of pollution focuses on groundwater that makes transboundary problems of river water contamination a so-called historic pollution. For example:

Waters of the Ilek River (a left feeder of the Ural River), being a transboundary river with the Russian Federation, are polluted with hexavalent chrome. This contamination of river waters is associated with entry of polluting groundwater of Quaternary alluvial transboundary aquifer that contains hexavalent chrome to the Ilek River near Aktobe city, Republic of Kazakhstan. This aquifer is unconfined. The historic focus of pollution of groundwater of this aquifer has commenced since 1957 after commissioning of Aktyubinsk chrome plant. As of 1992 the area of the pollution focus reached 14 km² at a content of hexavalent chrome of 0.7-3.8 g/l where MAC for drinking water is 0.05 mg/l. The flow of contaminated groundwater with a 4 km front moves towards the Ilek River. The scale of the problem of water pollution of the transboundary Ilek River with hexavalent chrome made local authorities to allocate funds to carry out research. As the result, a feasibility study of groundwater purification has been developed.

Two focuses of historic pollution of underground waters that predetermine the risks of pollution of the transboundary river are well known within the Irtysh River basin.

The first problem is the site of mercury pollution of the Quaternary alluvial transboundary aquifer of the Irtysh valley near Pavlodar. A close attention has been put to this problem. A mathematic modeling of the pollution site has been carried out methods of its elimination have been developed on international projects of UNDP and UNESCO (Tanton *et al.* 2003).

Another problem is associated with pollution of the Quaternary alluvial unconfined aquifer of the Irtysh valley near Semey by aviation kerosene. Many-years technological and accidental releases of fuel at the air base of air forces of the USSR has resulted in a catastrophic contamination of groundwater and formation of a large aviation kerosene lens occurring at the depth of 3-4 m below surface. The lens area is 0.42 km², liquid phase thickness – 0.5 m, estimate fuel reserves – 6500 t (as of 01.01.1992). Contaminated groundwater and floating oil products represent a threat to the water ecosystem of the Irtysh River. This lens was researched by KazHYDEC in the beginning of 1990th. Works were performed in 2000 in conjunction with HYDEC (Moscow) to prepare a feasibility study

for retrieval of kerosene and elimination of pollution. However, these works have not been completed. Today the lens slowly keeps moving towards the Irtysh River.

Group 2. Transboundary groundwater problems associated with quality and quantity of groundwater.

Reduction of resources and reserves of groundwater due to water use or any other activities performed on the adjacent territory, or polluted groundwater are delivered over the state border to the adjacent territory. In this event, the methods of integrated management of groundwater resources attain a certain transboundary (interstate) specificity. And risks of occurrence of such problems are estimating already at an inventory stage of transboundary aquifers according to typification of boundary conditions of groundwater flows.

Conclusions

The troubles in substantiation of number, location, and construction of monitoring stations, substantiation of programs and carrying out monitoring of transboundary aquifers, and assessment thereof due to a big number of transboundary aquifers and large areas of such transboundary aquifers (as this concept is defined in the international legal documents (Stephan, M.R, *editor*, 2009)) need to be resolved. For this purpose it is necessary to expand the scale of research of transboundary problems; to increase mapping scale of transboundary aquifers in the international coordination of taxons of hydrogeological stratification of a geological section and parameters of their showing on a hydrogeological map; on a basis of new interstate projects to develop some guidelines for research and management of transboundary groundwater resources in interstate aspect, and others.

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