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AQUIFER SYSTEMS

From geostructural point of view, the territory of the Azerbaijan Republic is represented by the Greater Caucasus, the Lesser Caucasus Mountain Ranges and the Kur-Araz Lowland lying between these two mountain ranges (Alekperov et al., 2008). The mountain structures of the Greater Caucasus and the Lesser Caucasus are composed of Meso- Kainozoic and Palaeo-Kainozoic rock formations, respectively. Thick weathered, fractured rock formations and inter-mountain troughs with soil content of alluvial and fluvioglacial sediments are specific features of both mountain ranges. A distinguishing geological feature of the Azerbaijani part of the Greater Caucasus is higher prevalence of sedimentary deposits. The layers composed of fractured and Karstic formations are much richer in water reserves, whereas volcanogenic and intrusive rock formations have less water content. Natural groundwater discharge locations / springs with approximate yields of 5-10 l/s are seen at the foothills. The springs with flow rates up to 60-100 l/s are encountered mostly in the areas with karstic limestone rocks. Significant stock of groundwater is available in 70-90 m thick alluvial deposits forming the substructure of riverbeds. Springs linked to underflow have yields varying from 0.5-1.7 to 25-30 l/s. Permeability of water-retaining rocks is 1.7-14.2 m/day. Confined and unconfined aquifers have been penetrated by exploratory wells with depths varying from 40-50 to 250-300 m. Level of non-pressurised groundwater varies from 0.1-1.0 to 60-85 m and yields of the wells are between 0.1 – 5.5 l/s. Yields of exploratory wells drilled into the confined aquifers vary from 0.8 to 12 l/s and the piezometric levels are both below (5-8 m) and above (0.8-4.0 m) the level of ground surface. Higher yields have been recorded in layers composed of sand and limestone sediments. Permeability of aquiferous layers varies from 0.1-0.2 to 12-15 m/day. Pressurised groundwaters of the Lesser Caucausus are associated mainly with tectonic faults and cracks. Recharge and transit of groundwater within the Greater Caucasus is facilitated by existing tectonic structure, weathering zones, numerous fractures and joint fissures, as well as structural and textural properties of flysch and metamorphic formations. These peculiarities create conditions for formulation of significant volume of mineral content groundwater. Thermal and mineral water sources are located in linear position as their discharge is associated with tectonic fault lines. Thermal waters are linked to main fault lines and cold mineral sources are linked to subfaults. Yields of mineral water sources vary from 0.01-0.02 to 2.8-3.7 l/s. The absolute majority of mineral waters of Azerbaijan are in the Lesser Caucasus. The famous sources include Istisu, Badamly, Sirab etc.

Piedmont and intermountain troughs forming the Kur-Araz lowland are considered to be basins of porous-fractured waters and are rich in fresh and low-mineralized (up to 3 g/L) groundwater. They are formed by confluent fans of Upper Pliocene-Quaternary ages, alluvial quaternary and alluvial-dealluvial strata, which are basically rather thick (up to 300-500 m, seldom 1000-1500 m). Almost all of these basins contain one unconfined and several confined aquifers (Fig. 1).

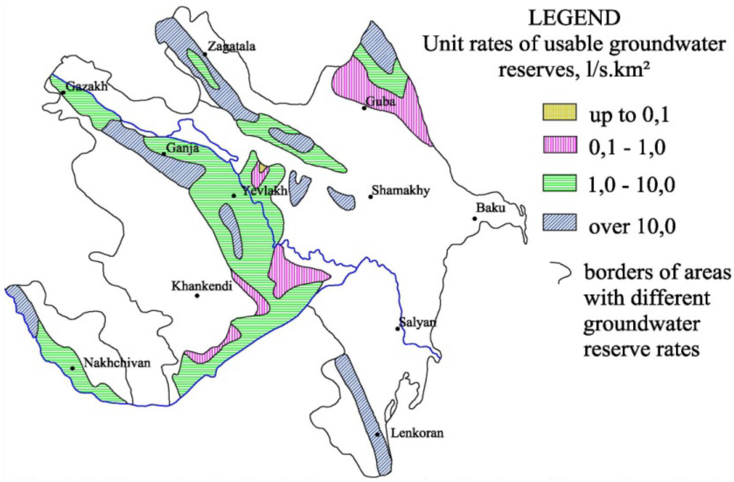

Figure 1. Groundwater in piedmont troughs, fresh and low-mineralized.

Unconfined aquifer exists almost everywhere along piedmont plains. Occurrence depth of non-artesian aquifers varies from 60-80 meters at foothill parts of alluvial fans down to several centimeters at discharge zones. Yields of wells drilled into unconfined aquifers vary from 0.1-0.2 to 25-30 l/s. However, the majority of yields is between 3-5 and 15-20 l/s. Discharge rates of springs fluctuate from 0.1-0.3 l/s to 15-20 l/s and may reach 280-300 l/s, though rarely. Permeability of the aquifer changes between 0.1-0.5 m/day and 25-48 m/day. Confined aquifers lie several kilometres below the contact zone of parent rocks and alluvial sediments. The confined aquifer has been penetrated by wells with depths varying from 10-20 m up to 110-300 m. Piezometric levels of pressurized water are both below (from 0-3 m to 70-80 m) and above (from +1+3 m to +20+50 m) ground surface. The flow rates recorded during pump tests are between 0.1-0.2 and 57-98 l/s. Permeability of the water retaining rocks varies from 0.1-0.4 m/day to 10-46 m/day (Alekperov et al., 2008).

The lowlands of Azerbaijan, mainly composed of continental marine sediments and merely marine sediments are distinguished for their unfavourable hydrogeological conditions.

Geostructural and lithofacial properties of piedmont porous-stratal groundwater basins and the common recharge sources give rise to tight hydrodynamic connection between the unconfined and the confined aquifers. The situation concerning the porous-fractured groundwater basins is rather different. Groundwater of the Lesser Caucasus originating from the fractures is associated with intrusions recharge local porous waters. In the Greater Caucasus, however, basic sediment fractures are fed by precipitation, i.e. porous-fractured waters have common recharge sources. There is no connection between groundwater reserves originating from different fractures.

USABLE GROUNDWATER RESERVES

Potentially usable reserves of fresh and low-mineralized groundwater in the whole territory of Azerbaijan are estimated to be 24 mln m^3/day (Alekperov et al., 2008). These reserves were estimated in 1970-1980, and no longer reflect a complete realistic picture, because of considerable changes that took place recently in water industry, as well as in qualitative and quantitative indices of groundwater sources. In fact, stock of usable groundwater resources is much larger than estimated. Annual groundwater production rate is between 3.0-3.5 bln. m^3.

GROUNDWATER QUALITY

Groundwater in the mountainous zones is of good quality. Total dissolved solid (TDS) content of spring waters is usually between 0.3-0.6 g/L and chemical contents include HCO_3-Ca. Groundwater under river beds is also of drinking quality with TDS content of 0.3-1,0 g/L and chemical content including HCO_3-Ca-Na and SO_4-HCO_3-Na-Ca. Slightly saline waters with TDS content of 1.3-1.4 g/L and chemical content of Cl-SO_4-Na are observed in the places adjoined to the sides of the river beds. TDS content of groundwaters extracted by wells drilled into the aquifers of the Greater Caucasus varies between 0.3-0.5 and 8-10 g/L and in the Lesser Caucasus this content varies between 0.3-0.5 and 20-22 g/L. Chemical status is quite heterogeneous with various combinations of anions and cations. There is a consistency in respect of chemical content and TDS content of groundwater in the Greater Caucasus. TDS content increases while moving from north-west to south-east and chemical contents shift from HCO_3-Ca to SO_4-Na due to several factors such as increased clay content of water retaining rocks, decreased rainfall and poor diversification of terrain.

Waters discharged by majority of these sources have lower TDS content (0.3-1.7g/L) with SO_4 Na-Ca-Mg composition and H_2S smell. Water temperature at some of these sources reaches 39-40^0C. The main distinctive feature of mineral waters of the Azerbaijani section of the Greater Caucasus is that water does not contain carbonic acid and almost all water sources are hydrosulphuric. In other parts the situation is different. Some springs contain iodine, bromine, boron, and silicates. Mineral water sources in the Lesser Caucaus have TDS content ranging from 0.5 up to 7.4 g/L. Water temperature in some sources reaches 51-74°C.

Fresh and low-mineralized waters are widely spread within piedmont plains depending on specific features of their geological structure, recharge and discharge conditions of the aquifers (Table 1.). In depressions (mostly peripheral zones of debris cones of Garabagh, Mill, and Shirvan plains) fresh and low-mineralized waters are shifted by very salty or salty waters due to influence of features mentioned above. Groundwater resources in Alazan-Ayrichay, Gusar-Devechy valleys and almost everywhere in Gyanja-Gazakh, Garabagh and Jabrail plains are of drinking quality. Higher TDS content characteristic of pressurised waters found in Neogenic formations spread along Gyanja-Gazakh, Garabagh, and Mil plains. The Garabagh, Mill, and Shirvan plains are distinguished for their complex hydrochemical state. For instance, in Garabagh and Mill plains, one unconfined and two confined aquifers contain mineralized water and the confined aquifer in between contains fresh water.

Table 1. Quality parameters of groundwater bodies in piedmont hills.

Indicators	Porous-stratal groundwater basins							
	Alazan-Ayrichay	Gusar - Devechi	Gyanja-Gazakh	Garabagh & Mill	Shirvan	Jabrail	Nakhchivan	Lenkoran
TDS, g/L	0.2-0.5	0.2-0.7	0.3-3.0	0.3-2.3	0.5-3.0	0.3-3.0	0.2-2.4	0,4-2,8
pH	6.7-8.2	6.9-8.2	6.5-8.2	7.4-8.4	7.5-7.7	7.0-8.1	6.6-8.3	6.6-8.2
Cl, mg/L	4 -110	4-980	4 -1900	10-1040	7-200	4-480	3-540	18-1420
SO_4, mg/L	14-132	12-206	4-1400	9-810	4-133	10-886	18-1270	7-229
NO_2, mg/L	up to 9	up to 10	up to 9	up to 10	up to 5	up to 9	up to 10	up to10
F, µg /L	up to 680	up to 1500	up to 1520	up to 800	up to 750	up to 1080	up to 1200	up to 600
Mn, µg/L	up to 30	-	signs detected	up to 90	N/A	signs detected	signs detected	-
Fe, µg /L	up to 10	up to 30	up to 125	up to 70	up to 50	up to 100	up to 25	-
Cu, µg/L	up to 60	up to 750	up to 200	up to 200	up to 500	up to 34	up to 100	up to 15
Zn, µg/L	up to 50	up to 4000	up to 400	up to 400	up to12	up to 160	up to 4200	up to 45
Sr, µg /L	300-700	up to 1400	up to2000	up to 1950	!50-1300	85-2000	p to 2000	350-2100
Pb, µg /L	N/A	up to 100	up to 90	5-80	up to 80	up to 100	up to 50	-

The plains' groundwater is salty, often very salty with solid residues totaling to 100-200g/L. Saline groundwater is widely used in Azerbaijan along with fresh groundwater.

QUALITY SUSTAINABILITY CONCERNS AND MITIGATION POSSIBILITIES

Sustainability of groundwater quality is an issue, linked directly with the state of main recharge sources i.e. surface waters and aeration zones. Groundwater reserves in the mountainous areas i.e. all porous-stratal and stratal groundwater basins are less endangered considering the conditions of natural protection. In piedmont plains, the first stratum from the surface of the aquifer is unconfined and not protected anywhere. Confined aquifers are naturally protected against contamination (Alekperov et al., 2006).

The chemical state and TDS content of non-pressurised water in mountainous areas and some areas of the Kura-Araz lowlands were influenced by natural seasonal changes. No variations influenced by natural conditions are observed in salinity and chemical content of pressurised waters.

Catchment basins of the two main rivers in Azerbaijan, the Kur and the Araz, occupy considerable parts of the territories of two neighbouring countries, Georgia and Armenia. Annual wastewater material and effluent disposal into the Kur and its tributaries in the territory of Georgia is approximately 330 mln m^3. The water of the Akstafachay River (the Kur's right tributary flowing through Armenia) contains chemical dye, oil products, phenol, ammonia nitrogen and other contaminants that are discharged into the river together with wastewater material in Injevan, Dilizhan and other Armenian towns. The rivers Alazan and Iori (left tributaries of the Kur River) also carry over contaminated waters from Georgia to Azerbaijan. While crossing the borders of Azerbaijan, the Kur River already contains oil products, phenols, and other contaminants in volumes exceeding admissible limits 2-6 times depending on periods: phenols 3-20 times, copper 7-14 times, sulfate 2-3 times. In the territory of Azerbaijan, contamination is enhanced by agricultural pollutants and wastewater from industrial premises and cattle farms.

Left tributaries such as Razdan, Arpachai, Okhchuchai etc of the Araz, Azerbaijan's second biggest river in terms of its length and flow, contain hazardous substances (nitrite nitrogen, ammonia nitrogen, heavy metals and other pollutants exceeding the sanitary norms dozens of times), which come from Armenia with water flow. Volume of annual wastewater disposal into the Araz River in the territory of Armenia exceeds 350 mln m^3. Every year the ore and copper-ore mining and processing enterprises discharge highly contaminated wastewater into the Okhchuchai River, which flows into the Araz River making it red-brown and almost black. The red-brown liquid contains high concentration of aluminium, zinc, manganese, titanium, bismuth and other components. After the confluence of Okhchuchay with Araz River, microflora content of the river is reduced by 65-80%. The main reason for this situation is the lack of effective drainage system, treatment facilities as well as technical insufficiency of existing plants in most towns and settlements of not only Georgia and Armenia, but also Azerbaijan.

In huge parts of the lowland, subsoil and aeration zones are exposed to natural pollution and Salinization rises sharply in poorly drained and drainless areas below the zero contour. Salinization rate in irrigated areas ranges from 0.25% to 1-2%. Local pollution of subsoil and aeration zones with organic and mineral fertilizers can be observed in irrigable lands and in the vicinity of fertilizer storages. Land plots around oil fields and industrial premises are also considered vulnerable in terms of contamination of subsoil and aeration zones by petroleum products and chemical agents. From time to time, concentrations of nitrates and nitrites in aeration zones of certain irrigable areas exceed admissible rates for more than 10 times. Aeration zones around fertilizer storages sometimes contain 1.7 to 97.7 mg/kg of nitrites. There are higher concentrations of nitrates, nitrites, phosphates, sulphates, chlorine, iron and aluminum around the sludge pit at the Ganja aluminum plant.

Groundwater pollution of regional scale has not observed in Azerbaijan. Pollution is of domestic, industrial and agricultural nature. The main factor causing domestic pollution is the lack of effective drainage system and purification facilities in most communities. Domestic wastewater is being disposed into the rivers, the sea, natural or manmade pits. Groundwater pollution is caused by infiltration of contaminated river water or migration of chemical agent via the zones of aeration. For instance, chemical elements such as phenol (0.007-0.13 mg/L), sulphates (960-1280 mg/L), Iron (0.5-5.0 mg/L), and BOD 5 (0.46-23.9 mg/L) were found in groundwater reserves in the vicinity of pits used for disposal of already treated sanitary and domestic wastewater coming from Ganja city. Aluminum (0.08-3.5 mg/L), iron (3.5-50 mg/L), phenol (0.008-0.004 mg/L), high concentrations of nitrites, nitrates, ammonia and sulphates were encountered in groundwater at sludge pit of Ganja aluminum plant.

Groundwater contamination with agricultural contaminants is observed mostly around fertilizer storages. Contaminants include nitrate, nitrite and phosphate, which exceed admissible rates by 2-5 times. Concentrations of nitrites and nitrates in irrigable lands do not exceed the admissible rate, while around cattle farms such concentrations may reach 10-19 mg/L and 12-145 mg/L correspondingly. Evidences of bacteriological pollution of groundwater have been recorded in irrigable areas, cities, cattle farms and near wastewater treatment plants. Contamination of pressurised water has not been observed.

The quality of groundwater in the coastal zones is affected by the rise of the Caspian Sea, which causes contamination in two ways: 1) chemical elements and combinations of sea water change the composition of groundwater via migration in the coverage areas of low-mineralized groundwater; 2) increased sea water occupies coastal lines composed of rocks with good condensing capacity and thus deteriorates conditions for formulation of fresh and low-mineralized groundwater.

To ensure sustainability of the groundwater quality, it is necessary to carry out comprehensive investigation of recharge conditions, hydrochemical and bacteriological composition of groundwater under the influence of rivers; to prepare diagrams for integrated use of water resources; to identify possible ways of avoiding pollution; to conduct independent monitoring of surface and groundwater flow; to restrict disposal of untreated wastewater into rivers at least in large cities and settlements; to construct drainage facilities and treatment plants for entrapment and neutralization of highly contaminated infiltrates in waters intended for irrigation purposes etc.

In recent years Azerbaijan has consistently carried out the restoration and construction of drainage network that drains the salty and polluted groundwater on huge areas along Kur-Araz lowland. Extensive work is being undertaken for the construction of sewerage network and treatment plants for large urban settlements and industrial plants. Such measures will significantly contribute to sustainability of groundwater quality.

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