Types and hydrogeologic features of surface and groundwater interactions in Uzbekistan

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Abstract The degradation of groundwater quality and quantity in Uzbekistan is a major problem for people in charge of drinking water supply. In order to guaranty a safe and effective access to the resource, it is necessary to estimate the quality of the resource and to evaluate the recharge rate and the residence time of water within the aquifer systems. This study presents a few attempts carried out to draw a first portrait of the real situation in Central Asia.

Keywords: groundwater resource, drinking water supply, surface-groundwater relationship, Central Asia

1. Introduction

Uzbekistan is a landlocked country in Central Asia, with a total area of 447 400 km². It is bordered in the north by Kazakhstan, in the east by the Kyrgyz Republic and Tajikistan, and in the south by Afghanistan and Turkmenistan. The cultivated land is estimated at 5.2 million ha. Mainly because of water shortage, the cultivated area is only 20% of the cultivable area, estimated at 25.4 million ha. From hydrogeologic point of view, the territory of Uzbekistan is divided into two parts – mountain and plain. Tectonically it is orogenic (post platform and mobile) belt of the Western Tian Shan and has complex geology. Hydrogeologically this zone represents a significant zone for groundwater development. The plain zone occupies the south-eastern part of the Turan plate and is characterized by almost horizontal arrangement of Mesozoic deposits on Palaeozoic base. Severity of the climate and plain relief causes the development of highly saline groundwater with limited resources in this place.

The average annual rainfall is about 264 mm. Two river basins are found in Uzbekistan. These basins form the Aral Sea basin: The Amu Darya basin in the south and the Syr Darya basin in the north. The total river flow generated inside Uzbekistan is estimated at 9.54 km^3/ year. The actual renewable water resources can thus be estimated at 50.41 km^3/year. The largest lakes are: Lake Aydarkul storing about 30 km^3 in 1995; and the Sarykamish and Sudochie lakes storing 8 and 2 km^3 respectively. There are 52 reservoirs in Uzbekistan with a total capacity of about 19 km^3. In 1994, the total annual water withdrawal for agricultural, domestic and industrial purposes was estimated at 58.05 km^3. This amount included withdrawal from surface water (46.16 km^3), from groundwater (7.39 km^3) and withdrawal from return flow collector-drainage for irrigation purposes, estimated at 4.5 km^3. The total water withdrawal increased steadily from 45.5 km^3 in 1975 to 62.8 km^3 in 1985, mainly because of irrigation expansion. Since 1990, when the water withdrawal was 62.5 km^3, the trend has been downward, due to agricultural water saving methods and a recession in the industrial sector.

Groundwater resources and particularly fresh groundwater have a strategic importance for Uzbekistan. Nowadays groundwaters contribute to 10% of total water resources and groundwater withdrawals for drinking water supply are significant (60% of drinking waters come from groundwater). So drinking water supply with fresh groundwater is vital today and will be even more strategic in future. There are 99 major aquifers in Uzbekistan, 77 of which provide fresh groundwater resources suitable for drinking water supply. Groundwater resources with mineralization up to 5 g/l are estimated to 24.09 km^3, and around 8.91 km^3 show mineralization up to 1 g/l. The most important groundwater resources are located, mainly in Ferghana Valley (34.5%), Tashkent (25.7%), Samarkand (18%), Surkhandarya

(9%), Kashkadarya (5.5%) provinces, and others in total represent only 7% of the resources. Renewable resource of groundwater is 8.34 km^3, of which 50% is for drinking purposes.

In 2002, the total water volume pumped for all purposes was 17.37 $mln.m^3$/day, of which 6.91 was pumped for drinking, 1.85 for industrial, 4.49 for irrigation and 3.82 drainage purposes. The analysis of the demand and resources indicate that Ferghana, Namangan, Andijan, Tashkent and Samarkand provinces have the capacity to develop its own water supply systems based on currently available explored fresh groundwater resources. The main shortage of water falls at western and southern provinces, where the groundwater resources are decreased due to extensive agricultural development and because there are no options for detecting and developing new aquifers exploitation. From 1992 to 2002, the total amounts of withdrawals decreased (from 28 to 17.37 $mln.m^3$/day) and till 1998 the withdrawals for drinking purposes constantly decreased too (up to 5.2 $mln.m^3$/day). From 1975 to 1992, withdrawals of the fresh groundwater resources had increased from 12 to 28 $mln.m^3$/day due to drinking water supply and irrigation developments. The extraction of fresh water in western provinces has decreased owing to depletion of fresh groundwater resources and its removal with surface reservoirs such as Tuyamuyun, Kuyimazar and Talimardjan; poor technical conditions of the pumping stations; lack of maintenance; and not reliable electricity supply.

In 2002, Uzbekistan had 45,000 wells drilled, of which only 27,000 (60%) are operational. The rest is not operated due to above mentioned and other reasons. The groundwater resources are continuously decreasing for last 30-35 years: if in 1965 its resources were 40.7 $mln.m^3$/day, in 2002 it has decreased to 16.3 $mln.m^3$/day, that is to say diminished by almost 40%. Hence, the understanding of the types of surface and groundwater exchanges will be extremely useful in recovering the diminishing aquifers and developing the fresh groundwater resources via available surface waters. The paper discusses the specific features of each type of water exchange and its evolution conditions; particular attention is given for the discussion of valley and pre-mountain types of water exchange since it has valuable practical (irrigation and drinking purpose) importance for research.

2. Water exchange types

On the territory of Uzbekistan there are 5 types of water exchange concerning various hydrogeological structures (Table 1). The length of the water exchanges of hydrogeologic structures and aquifers characterizes sensitiveness of its resources to the impact indicators (natural-technogenic factors of formation and use). The value of the exchange duration indicates the time after which there will be response to the impact of the groundwater resources. The most rapid response is typical for superficial fresh groundwater recharged by canals in the Amudarya Delta. Their resources are estimated to be 12% from total resources of groundwater in Uzbekistan (Borisov 1990). Artesian basins, according to the same information source consist of 13% of all groundwater resources of Uzbekistan; oppositely have highly retarded reaction to the influence – from 95 to 1480 years. Average duration of the water exchanges (18-50 years) is distinctive to the inter-mountain depressions, river valleys, premountain chains, debris cones. They consist of 75% of the total groundwater resources.

Type	Hydrogeologic structure	Length (duration) of water exchange, years	
		Epi-platform orogen	Turan platform
Semi-desert	Delta of the Amudarya River, canal-by and river-by fresh lenses of groundwater	-	> 1.0
Mountain	Hydrogeological massifs	0.95 – 2.6	2.1
Valley-premountain	Intermountain depressions, river valleys, premountain chains, debris cones	18 -50	20 - 40
Confined	Artesian basins	95 -640	170 –1480
Desert	Fresh lenses of groundwater in the deserts	-	< 650

Table 1. Type of water exchange in Uzbekistan

Each type of the water exchange has its specific peculiarity of the evolution of its groundwater resources. In all types of water exchange the process of gradual and constant qualitative change in the groundwater resources are determined by the differentiations of the input and output items of their water balances. These are reflected in the values of the regulated resources of groundwater. Regulated resources are interpreted in the publications from different views. Most of the researchers consider them as the volume of gravitational water in the confined aquifer in the zone of groundwater level fluctuations (Bindeman, 1963 and Geintz, 1967). Different views on regulated resources are expressed by Plotnikov N.A. (1959). He considered it as resource component of the balance, which goes to incoming to the aquifer and to the outflow from the aquifer. The idea was also supported by Mirzaev and his students (Mirzaev et.al., 1991). Thus, the regulated resources will be correctly viewed as regulated resources of the aquifers, cracks, complexes. Regulated resources of the aquifers jointly with the incoming and out coming components of the groundwater balance serve as a driving force for evolution of its resources. Evolution of resources of groundwater with respect to quantity in semi-desert and valley-premountain types of water exchange is determined by the cyclicity of the river flow. Distinctiveness of this is that 20th century was characterized before 1959 by an increase in the river runoff, and the latter 27 years (till 1986) by a decrease. In general 95-year cycle (1891-1986), water shortage years were also observed (Chub, 2000) but however we can conclude that 20th century was abundant with groundwater resources.

3. Evolution of groundwater quality

Evolution of resources of groundwater with respect to quality has its own specificity. The evolution consisted in the intensive development of the irrigated agriculture in Uzbekistan, re-allocation of the river flows (great infrastructural development mainly after 1965), decrease in geo-ecologic conditions which lead to the forming in its territory of regional regressive and trans-regressive variations of the groundwater quality (by mineralization and hardness) (Borisov, 1990). Average annual increase in the area of the pollution by mineralization and hardness in the Zaravshan River Valley was 25.5 km^2/year, when the hardness was 0.018 - 0.025 mval/l/year. The hardness for Akhangaran River was 0.037 mval/l/year. Trans-regressive degradation of the groundwater quality develops from the sources of the pollution down with the flow of groundwater. The average area of the distribution of the aquifer pollution in the irrigated lands is 5.6-5.7 km^2/year. The action of the degradation of the groundwater water quality decreases the groundwater resources of Uzbekistan in 30 years by 8.25 m^3/sec/year or 0.26 km^3/year (Table 2). The volume of the depletion in water for the period 1965-1995 was 7.8 km^3 or 28.8% of the total groundwater resources.

Indicators	Period of assessment, years			
	1965-1974	1974-1982	1982-1995	**1965-1995**
Duration of the study periods, years	9	8	13	**30**
1. Groundwater resources				
Changes,* m^3/sec:				
Total values	-115.41	-121.51	-10.46	**-247.38**
Fresh (up to 1.0 g/l)	-75.74	-202.08	-87.98	**-365.8**
With mineralization of 1.5 g/l and more	-39.67	+80.57	+77.52	**+118.42**
Average yearly changes,* m^3/sec/year:				
Total values	-12.82	-15.19	-0.8	**-8.25**
Fresh (up to 1.0 g/l)	-8.42	-25.26	-6.77	**-12.19**
With mineralization of 1.5 g/l and more	-4.07	+10.07	+5.96	**+3.94**
2. Regional exploitation resources				
Changes,* m^3/sec:				
Total values	-182.17	-190.19	+133.05	**-239.31**
Fresh (up to 1.0 g/l)	+80.65	-238.05	-3.85	**-161.25**
With mineralization of 1.5 g/l and more	-262.82	+47.86	+136.9	**-78.06**
Average yearly changes,* m^3/sec/year:				
Total values	-20.24	-23.8	+10.23	**-8**
Fresh (up to 1.0 g/l)	+8.96	-29.8	-0.3	**-5.4**
With mineralization of 1.5 g/l and more	29.2	+6	+10.53	**-2.6**
Notes* - decrease – 'minus', increase – 'plus'				

Table 2. The change in the values of groundwater resources and regional exploitation resources in Uzbekistan

To the most important decrease was imposed to resources of fresh groundwater which for a 30 year period fell from 12.19 m^3/sec/year or 0.38 km^3/year to 11.52 km^3 or 42.5% of the total resources.

4. Technogenic influence

Technogenic influence changes the natural evolution of groundwater resources not only in quantitative and qualitative senses. The degree of the quantitative transformation of the evolution of the groundwater resources were assessed through the coefficient of the technogenic transformation between supply and discharge. Into this calculation, the concept of balance of values between the artificial sources of supply or recharge of groundwater resources and natural processes is used (Table 3). Its analysis demonstrates that highly influenced sources of supply of groundwater were observed in Karakalpakstan, Khorezm, Bukhara, Syrdarya provinces. In the sense of discharges the most technogenically affected resources of groundwater were observed in all the provinces except Karakalpakstan and Samarkand.

5. Conclusion

The given information shows that main factors of evolution of groundwater resources in Uzbekistan are water exchange, time bound transformation of regulative resources, inheritance of the natural cyclicity of the river flow and technogenic influence on quantity and quality of the groundwater. The quantitative indicators of the evolution of groundwater cover a period of 48 years from 1947 to 1995.

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Table 3. Resources, regional exploitation resources of groundwater of Uzbekistan and their technogenic transformation

Administrative territories	Value of groundwater resources, m^3/sec					Regional exploitation resources of groundwater, m^3/sec		Ration of value of fresh groundwater resources to the total resources	Resources of groundwater by (m^3/sec):				Coefficient of technogenic transformation of groundwater resources by:	
	Total	Including:				Total	Including fresh groundwater (with mineralization of up to 1.0 g/l)		By supply including genesis		By discharge including genesis			
		By genesis		By types										
		Natural	Artificial	Local	Transboundary				Artificial	Natural	Artificial	Natural	Supply	Discharge
Republic of Karakalpakstan	66.1	8.7	57.4	8.7	57.4	65.1	-	-	57.4	8.7	24.8	41.3	6.6	0.6
Andijan Province	60.7	22.4	38.3	2.0	58.7	60.7	36.9	0.61	38.3	22.4	39.5	21.2	1.71	1.86
Bukhara Province	39.2	7.1	32.1	7.1	32.1	29.8	0.75	0.025	32.1	7.1	29.8	9.4	4.52	3.17
Djizzak Province	38.8	15.7	23.1	10.9	27.9	10.9	7.3	0.67	23.1	15.7	28.2	10.6	1.47	2.66
Kashkadarya Province	50	27.7	22.3	16.4	33.6	19.9	15.6	0.78	22.3	27.7	29.7	20.3	0.81	1.46
Navoiy Province	24.6	12.4	12.2	24.6	-	13.5	0.84	0.06	12.2	12.4	20.5	4.1	0.98	5
Namangan Province	88.6	37.5	51.1	9.4	79.2	88.6	38.3	0.43	51.1	37.5	40.6	48	1.36	0.85
Samarkand Province	83.8	42.4	41.4	23.9	59.9	63.5	50.5	0.8	41.4	42.4	49.1	34.7	0.98	1.41
Surkhandarya Province	63.4	41.3	22.1	6.5	56.9	48.2	29.1	0.6	22.1	41.3	37.8	25.6	0.54	1.48
Syrdarya Province	74.6	17.0	57.6	14.7	59.9	74.6	7.4	0.1	57.6	17	59.8	14.8	3.39	4.04
Tashkent Province	88.4	42.4	46.0	85.9	2.5	105.7	70.7	0.67	46.0	42.4	56.8	31.6	1.09	1.8
Ferghana Province	109.3	40.8	68.5	5.4	103.9	109.3	70.7	0.65	48.5	40.8	94	15.3	1.68	6.14
Khorezm	71.8	1.0	70.8	1.0	70.8	71.8	-	-	70.8	1	62.8	9	70.8	6.98
Total by the Uzbekistan	859.3	316.4	542.9	216.5	642.8	761.6	328.09	0.43	542.9	316.4	318.9	285.9	1.72	2.01