Case Study of Transboundary Aquifers in Yemen:
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ABSTRACT

The complex field hydro-geological researches are executed in Yemen. Some complexes of underground waters have a local distribution, and some of them are transboundary aquifers. Yemen and Saudi Arabia is located on the Arabian Peninsula and part of the groundwater flow comes to the Red Sea and Indian Ocean. At the same time penetration of the sea-water to the water-bearing strata presents certain danger to the costal water withdrawal. The executed researches have been taken as a principle mathematical models. On the basis of the executed complex hydrogeological researches by the author the estimation of natural and operational stocks of underground waters has been executed, places of creation of underground water basins are offered, ways of formation of stocks of underground waters to the largest wadi Hadramaut are studied.

Key words: arid territories, transboundary aquifers, underground reservoirs, irrigation, mathematic modeling

1. INTRODUCTON

Water resources are one of the most valuable components of the environment. Sustainable development of the countries to a greater extent depends on their state. Over 30 % of the world population lack access to a safe water supply and some do not have even basic sanitation. Every year over 50 millions of people are suffering from poor water. The United Nations General Assembly announced the beginning of the "Water for Life" Decade.

Arid territories (deserts and semi-deserts) occupy approximately 1/3 of the surface. When studying the World arid territories the scientists face various problems. The biggest one is lack of data on atmospheric precipitation, surface and sub-surface water flow (Kalinin, 1998).

2. OBJECTIVES

In presentation I would like to highlight the issue of water cycles variables in water management of transboundary aquifers wadi Hadramaunt (Saudi Arabia and Yemen). I had worked in Yemen for 3 years and tried to integrate the isolated data on water cycles and supplement it with the outputs of my own research. A series of field experiments had been carried out in the arid mountain and intermountain regions of the Yemen southern and eastern provinces. The main feature of the region was the lack of the regular scientific observation on the natural waters and absence of data about some of the regions. The data was collected on frequency and intensity of rain, specifics of flood in wadi, subsurface water levels, amplitude between rise and recession periods, quality of water (Kalinin, 1997).

The studied region is located in the Middle East. Two thirds of the population is involved in the agricultural production which is concentrated on the 5 % (percent) of the territory. The rest of the land (almost 95 %) are arid territories – deserts & semi-deserts.

In Yemen Republic a number of joint projects were implemented in specific areas by foreign and local experts during several decades. Nevertheless the projects dealt with specific issues – either – description of water supply source and recommendation of how to use it, or flood regulation issues besides drilling wells. All these projects did not allow to build up a complex view of the formation and distribution of water resources, as well as questions of water management.

For Yemen, which is located in the southern part of the Arabian Peninsula, the most significant problem is to increase the volume of the pumped-out ground waters from the artesian wells. This should be carried out due the running process of depletion of water resources.

Yemen land forms were formed under the active neotectonic movements of the earth's surface. Whole territory can be conventionally divided into coastal area, upland region and wadi Hadramaut area with intermittent riverbeds and springs. Wadi is an Arabic term used for valley with periodic surface or flood flow.

Climate in Yemen is tropical, which determines two different seasons: hot and relatively cool. Hot season coincides with the monsoon from Africa. Average daily temperature is 39 ^{0}C in the western part of the coastal zone and it reduces down to 30 ^{0}C in the eastern direction.

In hot season amount of precipitation is over 300 mm (Mukeiros and El-Dali). Air humidity in the coastal region is permanently high – over 70 %.

Relatively cool season starts in October and lasts till April. Daily temperature in the mountains is 23 ^{0}C in January, in wadi Hadramaut – 27 ^{0}C. Air humidity reaches 90 % in Aden. There are over 200 sunny days a year. Solar radiation is higher then in other parts of the world at the same latitude.

In the region there are no permanent large rivers and water reservoirs. Just one small permanent water flow exists on the surface of wadi Hajar.

Surface water is formed only due to the atmospheric precipitation – in the period of monsoon rains. The specific feature of the basin hydrology is the predominance of the mountain area of water supply over the plain area. Flood water flows on the surface to the sea more faster, then it infiltrates to the water-bearing strata. The temporary ground dams are constructed to increase the irrigated areas. Water for agriculture and to drink is located mainly underground.

Available land is limited. It constitutes around 1 % of the investigated area. Only 50 % of the population need in grains and vegetables is covered by agriculture.

Regular observations on underground water levels and its chemical content are not carried out in the provinces. Records on underground water consumption for irrigation and other needs are not stored. Indirect quantitative data on underground water consumption is being collected only in small areas and have eventual character.

3. RESULTS

The author had estimated the stock of the underground waters on the investigated area, which is used for drinking and agricultural purposes. The operational stock was estimated by analytical and mathematic methods. The map which was developed on this data might allow conducting the reconnaissance of the underground water. It was stated that a sufficient amount of underground water is located in wadi Hadramaunt as well as in the eastern part of Ramlat-es-Sabain desert (Saudi Arabia), where the estimated stock for the next 50 years would be over 10 dm^3 per km^2 in one second. Total potential stock of the underground water for 5 provinces of Yemen is estimated for the next 100 years of operation as 9,4 km^3 per year.

For the first time both the potential water resources for the mountain regions where they grow coffee as well as demand for water were estimated. A modulus map on exploited resources of underground water was build. It was estimated that potential stock of water for the coming 100 years is about 100 million m^3 per year. But for the sustainable development of the region the demand for water is around 107 million m^3 per year.

Natural resources of the underground waters are poor and do not provide future or existing demand for water.

As it was stated above the surface waters are formed mainly due to the precipitation. Floods take place once or two times a year. At the same time there are years when it rains up to 15 times or exclusively dry periods when surface waters are not formed during a couple of years. In such periods the river beds in wadi remain dry.

Rain floods of various intensity and duration are observed in monsoon periods. Depending on the place of formation the streamflows come either to the sea or to the mountain cavities. They also can be trapped in the deserts.

Permanent and temporary dams are built up to redirect the streamflows for the irrigation purposes but the construction of the dams is quite expensive, besides, evaporation leads to the high losses of water.

As one of the rational means of water consumption in the arid territories, it was suggested to create underground reservoirs. It means that, artificial mountain cavity would be used for accumulation and operation of the underground waters and streamflows. The complex hydrogeological study, which was carried out in the mountain area, pointed out 77 places for future underground reservoirs.

The estimation of the natural and operational stock of subsurface water was done for the biggest wadi of the Arabian Peninsula – Hadramaut by mathematic modeling on the base of data collected by the author.

As a result of the researches it was stated, that recharge of the water-bearing strata is replenished by atmospheric precipitation which is, however, not equal in the catchment area and unequally infiltrates to the ground water strata. If we conventionally divide total amount of precipitation into four parts it will be obvious, that one part infiltrates directly into limestone of seiwoon suite through ravine system, another, which is collected on the plateau comes first through cracks and karst cavities into limestone of Jezza suite, and, after that, infiltrates into limestone of seiwoon suite. The third part forms surface run-offs and flows into the main streamflows. It fills soil with water, recharge the alluvial strata both within inflow territories, and main valley, especially during high waters. The fourth part of precipitation which falls out in wadi Hadramaut, evaporates and infiltrates into alluvial-prolluvial sediments. If we take advantage of data on balance of surface waters during the spring, then we would notice that the first, second and fourth parts take 46 % of the water recharge, and the third part - 54 %.

Extremely important feature of water intake in the Cretaceous sandstone is the presence of a thick Paleogene limestone layer above, which accumulates significant volume of water in storm rains periods.

However as limestone and sandstone are alternated by clay soils, and water, which infiltrates into the clay soils, does not come directly to the lower sandy strata but spreads gradually. It means that limestone substitutes underground reservoirs which feed the main water-bearing strata. The value reaches its utmost in monsoon periods. It helps to keep the precipitation for water-bearing replenishment at a maximum extent in a catchment area and prevent from useless disperse of water in the form of surface run-off.

Natural stock of the underground waters is estimated in 350 km^3 in wadi Hadramaut. The main part is located in sandstones. Relatively small amount is placed in alluvial water-bearing strata – around 15

km^3. Aground 1500 wells needs to be constructed for water withdrawal with flow rate 2 000 m^3 per 24 hours each.

4. CONCLUSIONS

Some problems territories Arabian Peninsula still remain not studied. They are the following:

1. Role of precipitation condensation in the increase of the transboundary aquifers of the arid territories Arabian Peninsula.
2. Problems connected with the relic water (transboundary aquifers) which is 7 - 20 thousand years old.
3. Yemen and Saudi Arabia is located on the Arabian Peninsula and part of the groundwater flow comes to the Red Sea and Indian Ocean. At the same time penetration of the sea-water to the water-bearing strata presents certain danger to the costal water withdrawal.

Issues connected to the interaction of the sea-water and underground water in the costal areas of Yemen still needs solution.

Certain gains have been made in study of transboundary aquifers wadi Hadramaut (Saudi Arabia and Yemen). But a major effort is still required.

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