Amu-Surkhan Basin water use efficiency approach and its effect on energy saving

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Abstract. In the article, the efficiency of water management is analysed in the territory of Amu-Surkhan basin located in south of Uzbekistan. On the territory, water resources are formed in a rather high amount. However, due to large volumes of technical water losses and lack of reservoirs, excess water is discharged to the Amu Darya River. At the same time, during the irrigation period, there is a need to pump large amount of water from the Amu Darya river, which leads to large electricity costs. According to the results of the studies, options are proposed to increase water storing capacity and thereby reduce the volume of pumped water.

1. Introduction
Improving the efficiency of agricultural production is the most important task of the economic development of any country, as well Surkhandarya region of Uzbekistan where live over 2.1 Mio population. The climate of the region is subcontinental with warm winters and hot, dry long summers, when the temperature is often reaches 45-48°C. Food security in the region depends on water availability of the sectors of economy, especially irrigation. Surkhandarya River is the main waterway of the region and is formed from the co-influence of Tupolang and Karatag rivers with total length of 175 km and 13,500 km² basin area. There are also such small rivers as Sherabaddarya, Dashnabad, Obizarang, Sangardak, Khojaipak and others. Tupalang, South Surkhan, Uchkizil and Degrez reservoirs operate in the region with total capacity of 690 Mio m³. Numerous engineering canals, including Sherabad, Amu-Zang, Djarkurgan, Zang, Khasarbag, Akkapchigay, Kumkurgan and etc. are deliver water to satisfy demand of all branches of economy in the region depending on water. The Amu-Surkhan Basin Irrigation Systems Association (AS BISA) irrigates 326 thousand hectares farmlands of which 263 thousand hectares (81%) irrigated by pumping of water. Water demand consists of 3.835 km³ annual. In the area operate 1,566 km main and 10,616 km inter-farm canals and 1525 large engineering structures.

2. Main part
The study of water resources management in the Surkhandarya region revealed that 4,157 km³ water, however its beneficial use consists of 2,195 km³. Irrigation capacity of the Surkhandarya River, taking into account its flow regulation by South Surkhandarya and Uchkizil reservoirs, consist of 2,120-1,900
Mio m³ a year at 75 and 90 percent provision accordingly. The part of water is lost among irrigation network and on the irrigated fields. Taking into consideration a return water use the water deficit consists of 230-550 Mio m³ depending on water availability of the year. To meet the water demand, machine irrigation is functioning in the region. In order to improve water supply to the territories of the Dzharkurgan, Kumkurgan, Muzrabat and Termez districts, water withdrawal from the Amu Darya River takes place by pumping to the Amu-Zang, Kattakum and Jayhun canals. At the same time excess flow of Surkhandarya and Sherabad rivers can be discharged to the Amu Darya River (Figure 1).

Average monthly water withdrawal from the river varies from 25 to 70 m³/s with high discharge at vegetation period from April to August (Figure 2). Pump stations quantity and their specification is presented in the Table 1, where pumping water discharge from the river is equal to 330 m³/s.

**Table 1.** Water pumping capacity in the region.

| Pump stations belong to | Quantity of pump stations | Quantity of machines/pumps | Capacity, kWt | Discharge, m³/s |
|-------------------------|---------------------------|---------------------------|---------------|-----------------|
| State Pump Station Dept. | 113                       | 557                       | 642540        | 111             |
| Farmers                 | 705                       | 745                       | 76562         | 218.5           |
| Total                   | 818                       | 1298                      | 719102        | 329.5           |

Total capacity of water lifting in the region consist of 980,3 m³/s, annual volume of lifted water is equal to 3097,4 Mio m³, energy consumption is 930,4 Mio kW , energy and pump stations maintenance cost is over 22.5 Mio USD a year. At the same time over 30 percent of so expensive water can be lost within out-of-dated irrigation infrastructure. Study of the operation and management of the canals and hydro-engineering structures show, that there are ways of efficient regulation of water resources in the Surkhandarya and Sherabaddarya basin directed at decrease the volume of water delivered by pumping.
The Ministry of Water Resources is implementing the project “Improvement of water resources management in Surkhandarya region: reconstruction of Khazarbag-Akkapchigay canal network” funded by the IBD. The canal takes water from Tupalang River and connected to Sherabad Main Canal for improve water supply of the Sherabad massive (ex-Sherabad desert). The project made enable to turn off several pump stations at the Sherabad Main Canal system and allow water delivery by gravity. The lifted water volume is decreased to 7% against 23% before the reconstruction works (Table 2). As seen from the table, the Kizirik, Muzrabat, Jarkurgan, Kumkurgan and Termez areas machine irrigation share and accordingly energy consumption also too high.

Table 2. The irrigation canals and pump stations allocation among the districts of Surkhandarya region.

| №  | District  | Irrigated area, hectares | Length of canals, km | Pump stations | Irrigated by pumping lands, hectares | Energy consumption, Mio kWh |
|----|-----------|--------------------------|----------------------|---------------|--------------------------------------|-----------------------------|
| 1  | Kizirik   | 41900                    | 1029                 | 7             | 23330 (56%)                          | 46.504                      |
| 2  | Sherabad  | 36168                    | 1052                 | 3             | 2600 (7%)                            | 3.807                       |
| 3  | Denau     | 32279                    | 1855                 | 4             | 323 (1%)                             | 1.788                       |
| 4  | Muzrabot  | 27324                    | 851                  | 7             | 13750 (49%)                          | 34.500                      |
| 5  | Kumkurgan | 25585                    | 1040                 | 16            | 9130 (35%)                           | 176.300                     |
| 6  | Jarkurgan | 23021                    | 649                  | 11            | 22180 (96%)                          | 169.391                     |
| 7  | Angor     | 19098                    | 681                  | 3             | 1000 (5%)                            | 0.713                       |
| 8  | Shurchi   | 14340                    | 930                  | 6             | 1498 (10%)                           | 3.579                       |
| 9  | Termez    | 13437                    | 484                  | 24            | 7031 (52%)                           | 229.190                     |
| 10 | Sariosiy  | 9040                     | 913                  | 6             | 1760 (17%)                           | 3.942                       |
| 11 | Oltinsay  | 8891                     | 678                  | 6             | 1840 (21%)                           | 5.766                       |
| 12 | Boysun    | 4841                     | 166                  | 1             | 600 (12%)                            | 10.339                      |
| 13 | Uzun      | 4170                     | 288                  | 23            | 858 (21%)                            | 40.114                      |

The study of the pumping equipment technical specifications and current state has shown that major part of the pumps serving more 20 years and life time is fully exhausted. In addition, the engineering structures constructed that time also morally obsolete, there is a huge loss of water and energy. 229 pumps of total 557psc have served more than 20 years, 110 pieces - more than 15 years, 88 pieces - more than 10 years, 72 pieces - more than 5 years (table 3). Only 53 pumps (9.5%), which served up to 5 years, are equipped with energy saving techniques.
Table 3. Pumping stations energy consumption data and operation costs.

| № | Name                                | Units of measure | Quantity   |
|---|-------------------------------------|------------------|------------|
| 1 | State pump stations                 | PC               | 114        |
| 2 | Pump units                          | PC               | 557        |
| 3 | Energy consumption                  | Mio kWh          | 930.375    |
| 4 | Irrigated area                      | thousand hectares| 262.7      |
| 5 | Pumping cost                        | Mio sum          | 214178     |
| 6 | Energy consumption for pumping of 1000 m³ water | kWh | 173.36 |

Total number of pumping units: 557 pcs, Exploited period of pumps:
- > 20 years: 229 pcs
- 15-20 years: 110 pcs
- 10-15 years: 88 pcs
- 5-10 years: 72 pcs
- < 5 years: 53 pcs

3. Results and discussions

Water resources management system in Surkhandarya region has been studied including water facilities operation considering water demand and water availability, water distribution scheme and its efficiency, water lifting, energy consumption and energy saving opportunities. Construction of large reservoirs and extensive irrigation has changed balance between north and south region’s water resources, with positive and negative consequences. In the southern areas water supply sharply decreased due to significant water intake for irrigating of crops in the northern zone. To compensate the deficit, water is pumped from the Amu Darya River. Water demand in the region ranges from 3730-4450 Mio m³, including irrigation water of 3660-4305 Mio m³. Use of water resources in other sectors of the economy varies by following: communal service 19-20 Mio m³, industry - 17-18 Mio m³, fisheries range around 14-15 Mio m³ and others are 9-10 Mio m³.

Unsatisfactory water supply is based on the fact, that there is a great dependence on pump irrigation, which covers over 80% of the total area and consumes 70% of the annual budget of the Amu-Surkhan BISA for the operation and maintenance of pump stations, irrational water distribution and large unproductive water losses about 40% of total. Average annual 4157 km³ water is formed in the region, but its useful use is 2195 km³. Considering a high sensitivity to climate changes there is a forecast of 50% water deficit by 2050, which will lead to drought and further desertification of the area.

Significant volume of water discharges into the Amu Darya River are carried out in April-June and the average long-term values range from 40 to 95 m³/s, the average annual value is 735.4 Mio m³, i.e. total discharges equal to half of pumped water. If water resources management would be efficiently conducted, instead of pumping 1320.53 Mio m³ of water, it would be enough to pump only 585.16 Mio m³ of water.

The study of the situation allows to develop recommendations on improving of water resources management by modernization of the irrigation infrastructure, redistribution of available water resources within the Surkhan and Sherabad River basins, maximum reduction of water losses, as urgent tasks, solution of which will lead to increase efficiency of water resources use. To achieve the aims of this research work the following products were developed: water balance calculation software in the irrigation systems of the Amu-Surkhan basin based on MS EXCEL taking into account the irrigated areas; GIS modeling with a database of basin water management facilities: watercourses, water management facilities (canals, hydraulic structures, reservoirs, pump stations, gauging stations, etc.) based on ARCGIS, including a 3-D format; in the development of a flat map, a 3-D map was built with the characteristics of the terrain, slope and altitude using the tools included in the GoogleEarth package, which can track all the necessary parameters interactively. The modelling
results allow to identify a new water reserving and transfer opportunities as: Obizarang water reservoir with 100 Mio m³ capacity, Khangarang water reservoir with 6,1 Mio m³ capacity, Laylakan and Sherabad water reservoirs with 100 Mio m³ capacities, Sarijuy canal (2 m³/s) water transfer to Chilmirob canal (3 m³/s), R-2 canal water transfer to K-1 canal and Khazarbag-Akkapchigay canal water transfer (50 m³/s) to Sherabad canal. In addition, there is planned to modernize three existing hydropower stations with a production of 1.67 billion kWh annually. Some projects are started in the region to increase capacity of the reservoirs. The project planned to increase volume of the Tupalang reservoir to 500 Mio m³ by end of 2018 has been completed. Energy generating capacity of the station is increased by 175 MW, and average 430 million kWh electricity will be generated annually.

4. Conclusion
To improve the irrigation systems of the Amu-Surkhan basin it is recommended to upgrade the irrigation network (canals, reservoirs and pump stations), increase water storage capacities, maximum reduction of water losses, as the main directions of irrigation development, which is an urgent task, and solution of which will lead to increase of water resources use efficiency. In the region, there are opportunities to solve water shortages by redistributing the flow of water resources in the Surkhandarya and Sherabaddarya river basins, which will reduce the amount of water supplied by pumping from Amu Darya River to irrigation systems. Creating a new scheme of distribution of river flow between the basins is achieved by GIS modeling and programming of the irrigation systems network for calculating of water balance, which significantly reduces the financial costs associated with energy consumption.

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