MEASURES, TAKEN FOR PREPARING UNDERGROUND WATER SOURCES TO BE USED IN CASE OF EMERGENCY

I. Normatov and A. Kireev

Institute of water problems, hydropower and ecology Academy of Sciences of Republic of Tajikistan, 12, Parvin Street., 734002, Dushanbe, Tajikistan, email: owp@tojikislon.com

ABSTRACT

By the end of 19th century there were about 7-8 million people in the region. Irrigated land amounted about 3.4 million hectares and was equipping by an irrigation network. Today the region's population has increased seven-fold, and irrigated areas have broadened twice – up to 7.5 – 7.7 million hectares. Arid climate and irrigated nature use contribute to land and pasture land degradation, which leads to significant decrease of agricultural productiveness. Significant parts of irrigated areas are subject of salinization, which is 16% and above in Tajikistan, up to 30% in Kazakhstan and about 70% in Turkmenistan. Therefore, today the decision of tasks in the field of melioration and obtaining the supplementary sources of irrigation water has great importance.

Key words: salinization, superficial, underground, geomorphological, artificial

1. INTRODUCTION

The concept Central Asia (the former name is Middle Asia and Kazakhstan) that is used nowadays includes the republics of CIS: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Afghanistan. Hydrographically the Central Asia Region (CAR) is distinguished as the Aral Sea basin, which in its turn consists of two basins – the Syrdarya and the Amudarya Rivers.

The main indicators of technical and economic development of Central Asian economic region are given in Table 1.

Table 1. Indicators of macroeconomic development of CAR

Country	Territory, th. km^2	Population, mln. people	Per capita gross inland output by purchasing capacity parity, thousand dollars/man	Per capita energy consumption, tons of conventional fuel /man
Kazakhstan	2636,20	14,95	3,56	3,67
Kyrgyzstan	198,50	4,90	0,68	0,66
Tajikistan	143,10	6,20	0,99	0,84
Turkmenistan	488,00	4,70	1,52	3,30
Uzbekistan	447,36	24,60	2,26	2,70
CA	3913,16	55,35	2,22	2,64

Total water resources of the Aral Sea basin surface waters make 115,6km^3/year (Table 2). According to approximate evaluation underground water resources in the Aral Sea basin make 43,7km^3/year, 15,8km^3/year (36,2%) of them being approved exploitation reserves. Moreover, a large quantity of return waters formed in the Aral Sea basin – 45,8km^3/year, a small part of which is only repeatedly used for irrigation – 6,0km^3/year, and a great part of the waters led to rivers (23,5km^3/year) and natural reduction (16,3km^3/year).

Evaluation of these resources adequacy for Central Asia is ambiguous. If we compare them with leading countries with similar climatic conditions, first of all with Israel, we can make a conclusion that water resources available today are quite enough when using modern technology of water usage (Table 3).

Table 2. Surface water resources of the Aral Sea basin

Country	The Amudarya River basin, km^3/year	The Syrdarya River basin, km^3/year	The Aral Sea basin	
			km^3/year	%
Kazakhstan	—	4,50	4,50	3,9
Kyrgyzstan	1,90	27,4	29,30	25,3
Tajikistan	62,9	1,1	64,00	55,4
Turkmenistan	2,78	—	2,78	2,4
Uzbekistan	4,70	4,14	8,84	7,6
Afghanistan	6,18	—	6,18	5,4
CA	78,46	37,14	115,6	100,0

Table 3. Specific consumption of water in Central Asia and Israel

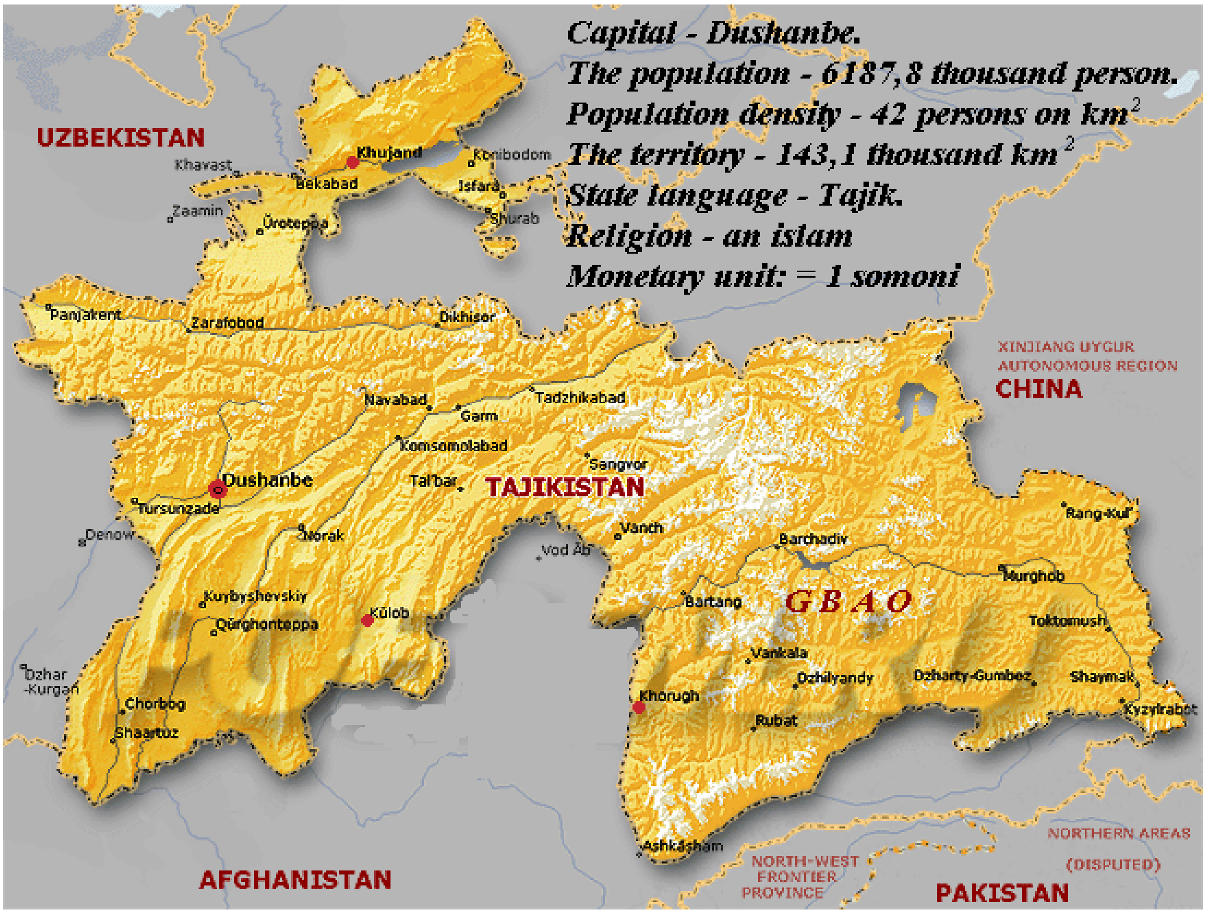
Indicators	Central Asia	Israel
Total specific consumption per capita, m^3/year	345,0	2875,0
On irrigation, m^3/year	5590,0	12887,0
The same, taking into account natural precipitations, km^3/ha	10,390,0	14690,0

The principal spheres of water resources use in Central Asia today are irrigated agriculture and hydroelectric engineering.

Irrigated agriculture appearance in Central Asia refers to the sixth-seventh century B.C. Since then up to nowadays its role has been constantly growing, irrigated areas have been increased. By the beginning of the twentieth century about 3,5 mln ha have been already irrigated in the region. Intensive development of irrigation in the region especially began during existence of the USSR (mainly from the 60th up to the 90th of the past century).

As a result by 1990 total area of irrigated lands in the region has increased up to 8,8mln ha, including:

- in Kazakhstan - up to 2,8mln ha
- in Kyrgyzstan - up to 1,1mln ha
- in Tajikistan - up to 0,7mln ha
- in Uzbekistan - up to 4,2mln ha



Tajikistan possesses unique water resources. With 93% of its territory covered by mountains, Tajikistan contributes more water to the Aral Sea Basin than all the other Central Asian countries combined. The area of glaciers (8% of the country) exceeds that of agricultural croplands (6%). Among CIS countries, Tajikistan is second only to Russia in terms of volume of water resources; and with a population of only 6.5 million, Tajikistan's annual water production of 13,000 cubic metres of water per person per year is among the highest in the world.

With its predominantly agricultural base, 84% of the water in Tajikistan goes to the fields, while 8.5% of consumption is accounted for by drinking water and communal services, 4.5% by industry and 3% by other uses, such as fisheries. These numbers do not capture the entire picture, however: 43% of the population has no access to piped water and nearly 25% of the population uses irrigation channels as its main source of drinking water.

Access to piped water was never 100% in Tajikistan. The mountainous topography of the country presents major physical challenges to extending the water supply network. According to UNICEF, 57% of the population (3.7 million people) is covered at present, including 93% of the urban population and 47% of the rural population.11 Just over 10% (650,000 people) use spring water, 3.7% (235,000 people) use river water, and nearly 25% (1.52 million people) use water from gorges, canals, irrigation ditches or pools. Access to piped water does not mean simply access to safe drinking water.

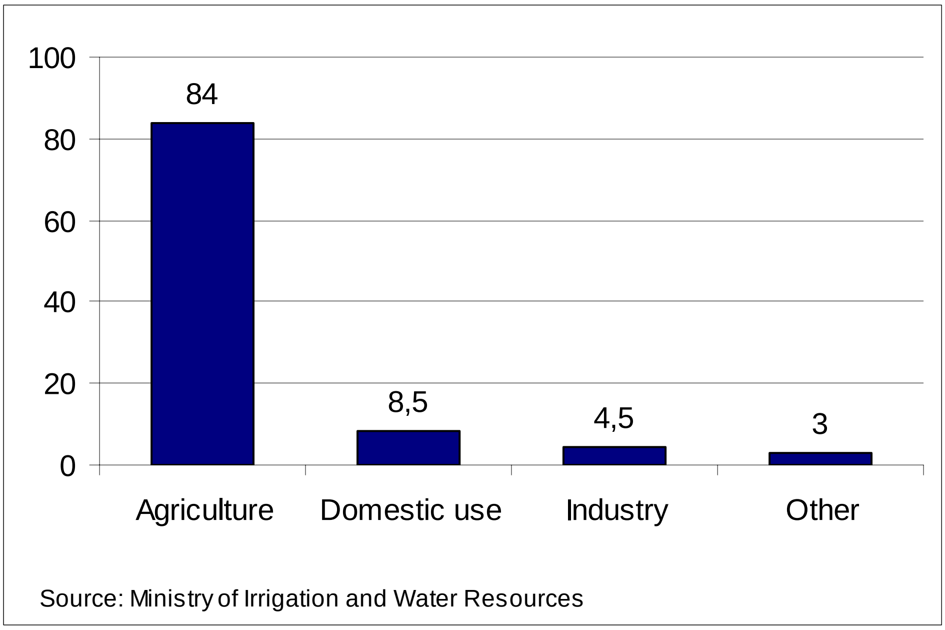


Fig. 1. Water uses in Tajikistan

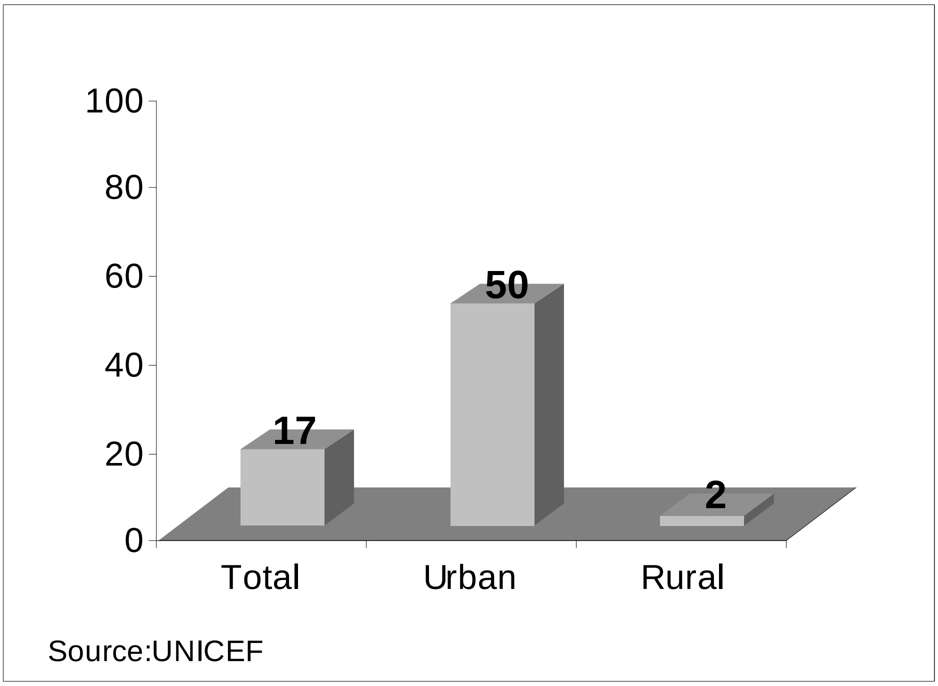


Fig. 2. Access of population to a sewage system

1.1. Measures, taken for preparing underground water sources

In a feed of underground waters from the outside, atmospheric precipitation and, probably, condensed water generally participate of republic on irrigated grounds superficial and underground waters. But in most cases dominating, powerful and constantly acting source of feed for underground and pressure underground waters of quaternary deposits are filtered loss of superficial waters coming through in ground from channel, an irrigate network, watering cards and downturn with throwing waters. On other feed sources in a number of cases it comes only the share of percent from general coming balance clause of underground waters from the located above grounds. At existing water use for such feed of underground waters is spent up to 30-50% and more from common water – gate of superficial waters in irrigated system.

The marked above picture of a feed and expenditure of underground waters is characteristic as a whole for of irrigated grounds of republic. But between their separate geomorphological elements the precisely expressed distinction is in this respect observed. On grounds with of deposit earth waters on depth more than 3-5 m the basic power supply of underground waters are filtered loss of superficial waters. On these grounds the drain of underground waters from an external mountain frame is directed also. In most cases size this within the limits of tens and hundreds l/sec. An objective large parameter in this respect is the small area of cross section irrigated alluvium caught of terrace, on which is carried out under channel a drain of earth waters from mountains. The capacity of alluvium here is usual no more than 5-10 m, and width of caught terrace – within the limits of several tens and, at the best, of hundreds meters. Earth waters of a considered part of foothill plain in the party of the located below files and in separate rare cases in a local hydrographic network are spent, and mainly without essential change of a degree them mineralization and chemical structure (as the drain occurs mainly on well washed out more thickly pebbles). But such drain already has essential meaning in an additional feed of underground earth and pressure head waters on the grounds, located below on a flow, a plain part of foothill plain (bottom part of cones carrying out), described weak natural draining and superficial deposit of earth waters. Besides here horizontal moving of filtered waters itself of irrigated system in the party of local downturn already matters also, where they are spent for collectorial – drainage dump and total evaporation from a soil cover. On such grounds these factors dominate in account clause of balance of underground waters. Their smaller part is spent usually considerably for a underground drain in a local hydrographic network on the normally advanced cones carrying out.

On old-irrigated grounds basic mass of underground waters, formed on them, makes horizontal moving on well washed out pebbles without essential change of a degree of mineralization and chemical compound.

The significant area of spreading powerful pebble water-bearing horizons provides an opportunity of creation in them practically of unlimited adjusting capacity. Preliminary in them operating a level of underground waters on 5-10 m and more can ensure adjusting capacity, in most cases quite sufficient for use water-bearing pebbles of horizons as underground reservoirs for seasonal and of many-years regulation of a drain of yet not used part of superficial waters (plenty of flood waters and not vegetative the period).

Water-bearing horizons in pebbles, described raised water -permeability, large square spreading and significant total powerfulness, practically provide an opportunity of development of a wide network of high-efficiency chinks of a vertical drainage and centralized economical drinking water supply. Debit of them can make from tens up to 100-200 l/sec and more, and effect drainage many tens and hundreds ha.

On the basic objects of irrigation of Northern Tajikistan and Kizilsu-Yakhsu valleys the network of such chinks can supply the most economic joint decision (in comparison with machine irrigation in a combination with horizontal drainage) tasks on melioration of irrigated grounds and covering of deficiency in irrigated to water. On the water-supplied objects of irrigation, requiring in land improvement of the salted grounds " the chinks in pebbles can ensure more economical decision of meliorative task with passing use of basic weight pumped out fresh and concerning fresh underground waters for irrigation and washings, and also for centralized of economical drinking water supply having here and important meliorative meaning (at the expense of the termination winter water serving for this purpose on irrigating network). Marked debit in most cases is possible at downturn of a dynamic level on 10-15 m (specific debit from 3 5 up to 10 l/sec and more) and depth of chinks about 50-100 m. Deposit of chinks of a considered type, in the volume number by a diameter up to 800-1200 mm, is provided already with available self-propelled machine tools high-speed rotor drilling with direct and return washing. The large diameters of drilling simplifying a task of creation of the powerful grave-sandy filter around stranger of a chink sharply reduce at the end specific cost of pumped out underground water.

The rather small productivity existing horizontal drain in cover small-ground is conditioned sometimes not only lowered filtered ability the last, but also small dip of drain is direct under a level of underground waters. In particular, it is caused also by that in already wetted and strongly becoming swollen small-ground practically was not presented possible to put in pawn deeper drainage. Taking into account this phenomenon, on again mastered virgin grounds the drainage should be pawned still in dry well steady small-ground.

At pumping out is superficial (0-2 m) deposit of underground waters from a single chink or their small group, when they do not cover completely file subject land-improvement, in an external contour already on small distance from a chink the depth up to a water mirror can be of less design norm of drainage. Here, alongside with outflow to a chink, earth waters will be spent and for total evaporation from a soil cover. Naturally, at the expense of such joint action, chink and the evaporations the general area drainage and radius of action are increased, but the area with design norm of drainage can make only small part from potentially possible (proceeding from volume pumping out and size of the drainage module). So, at joint work of five chinks the area of grounds with design norm of drainage from potentially possible can make only about 30-40 %, and at work of one chink - even 5-7 %. Unfortunately, this situation is not yet clear to a wide circle of the experts - designers and hydrogeologists.

In result, giving the overestimated estimation to the drainage module and underestimated of hydraulic interrelation between earth and pressure head waters, they provide the overestimated quantity of chinks of a vertical drainage at scope by last meliorated of files as a whole.

The stocks of underground waters are expedient for considering together with basic irrigate - land-improve by parameters of irrigated grounds of republic.

2. THE STATE OF ARTIFICIAL DRAINAGE IN TAJIKISTAN

In Tajikistan the underground waters for irrigated lands are spent mainly on natural and artificial drainage flow and the total evaporation from the ground surface. The very fact of evaporation from the ground surface is the cause of that there are still great areas of salinized lands. At the first stage of developing the virgin lands with the shallow soil the main part of filtration losses is to fill up the volume (static) store of underground waters, thus causing the corresponding rise of their level.

The surface and underground waters in Tajikistan are characterized by the considerable variety in mineralization degree and chemical composition. The least mineralized groundwater is observed near the filtration river sites and irrigation cannels. The most marked difference in chemical composition of republican irrigation waters is observed in chloral ion contents, on the base of which the evaluation of ground salinization degree is given for the areas with sulfate and sulfate chloride salinization.

It is possible to establish some laws in changing of mineralization and chemical composition of underground waters in quarter deposits on irrigated lands, taking into account the chemical composition of irrigation waters of Vakhsh River and river waters in Hissar Valley. Irrigation waters of Vakhsh River contain up to 0.1-0.15 g/L of chloral ion. As to river waters of Hissar Valley, its content decreases to 0.002-0.004 g/l. Compared to Vakhsh Valley the precipitation in Hissar Valley is 2-3 times higher, the total evaporation from the ground surface is some times lower, and groundwater running is higher.

It should be mentioned that in Tajikistan the land salinization does not result in falling of free soluble salts into solid sediment. This is explained by the fact that lands in Tajikistan, which are subject to salinizing, are characterized by the running of groundwater. At the same time sulfate and other more hardly soluble salts fall into solid sediment, right up to forming the independent layers in soil grounds.

Lands, irrigated for the long time, are characterized also by comparatively broad development of ground salinization. The part of these lands in the republic is over 116,000 ha. This situation is caused by the scanty development of drainage or its neglected condition, and as well by the insufficient depth of horizontal drains. As to amelioration, the only thing is poor – in conditions of two-tier geological structure of these lands the main part of salts is focused in the most upper layer of soil grounds. At the same time limited salt store and broadly developed bedding pebbles, which easily absorb water, with fresh subterranean and forceful waters are potentially favorable factors for relatively fast ameliorative improvement of these lands, if vertical drainage is possible to apply.

In the republic the average part of horizontal drainage is 20 m/ha. According to data, obtained from large-scale topography, the average part of lands with the depth of groundwater to 4 meters, when they my influence actively the ground surface, is about 37% of the total topographed area. About 60% out of them are salinized to a different degree, including 20% of greatly salinized lands. The total area of salinized lands correlates with the areas, where the groundwater (mineralization is over 2 g/L) lies in the depth of 2 m. The area of greatly salinized lands correlates with that, where mineralization of groundwater is over 5 g/l.

On lands, irrigated for a long time the maximum level is observed almost everywhere in August-September, irrespective of their geomorphologic geological structure. Minimum level is observed in February-March. This course in level regime of groundwater is caused by the corresponding consumption regime of river waters and water supply for irrigation. It disguises the role of the rest factors, on which the level regime depends, including such a great one as the total evaporation from the ground surface in the hot season of the year.

But the considerable change in level regime in future may occur on the land massifs, where vertical drainage will be applied. As a result of pumping out on vast territories the level may be on the depth of not over 3-5 m, when its regime fluctuations have no ameliorative meaning.

Mineralization and chemical composition of subterranean and forceful waters on irrigated lands in Tajikistan are also subject to regime changes. According to year seasons the most marked changes in this respect are observed on greatly salinized lands. There in the hot season of the year the groundwater of the surface shallow grounds with sharply increased mineralization is spent on the total evaporation from the ground surface, thus increasing temporarily the salt store in the soil grounds of aeration zone and on the land surface. The waters with lesser mineralization come to their place from the bedding pebbles. By the next vegetation period the adverse effect takes place – salts dissolve in the groundwater due to precipitation.

Large-scale application of vertical drainage on salinized lands will cause the gradual freshening of groundwater in the surface shallow grounds. But in the upper horizon of bedding pebbles, through which primary initial store of salts will be pumped out, the gradual increase in forceful waters mineralization will be observed for a number of years until at least on-time change of initial water store takes place within the whole range of rocks, which participate in pumping out. In consequence, a gradual decrease mineralization of pumped out water may be observed. Finally, after corresponding stabilization under new conditions, mineralization degree of groundwater will be defined by the difference between for the total evaporation from the ground surface and the total depth filtration water throw from the irrigation network into exploited water-carrying horizon.

Mineralization and chemical composition of forceful waters of the second, third and deeper horizons (100-150 m) under the influence of vertical drainage in the most upper one (the first) will not be subject to considerable changes. The water from these horizons, as the least subject to pollution, is worthwhile being used for centralized water supply.

The essential change in mineralization and chemical composition of groundwater should be expected on the developed virgin lands with thick surface shallow grounds. At the first stage of developing these lands the descending waters currents will wash the salts out of the upper layers and transmit them into deeper horizons. When at the next stage the level approaches the day surface, the groundwater may have already somewhat less mineralization than at the initial state. At this moment the artificial drainage must begin functioning, gradually throwing the water and salts out of irrigated lands. The drainage flowing may be up to 30-40% of the total water-intake into irrigation systems. Due to this correlation between water-intake and the surface throw of drainage and thrown waters, the groundwater, already suitable for irrigation, may gradually being formed in the zone of active influence of drainage.

Filtration coefficient of water-carrying pebbles changes from the tenth parts of meter up to many tens and more meters per day along the separate irrigation sites. According to data from the main part, on the main irrigation massifs the value of filtration coefficient varies from 10-20 up to 30-40 meters per day.In the upper layer of the surface shallow grounds, which is 3-5 meters thick and functions more actively under horizontal drainage, the filtration coefficient in most cases is 0.1- 0.5 m/d.

The considerable area, where the strong pebbly water-carrying horizons are spread, gives an opportunity to create almost unlimited regulation capacity there. The preliminary cutting off the level of underground waters by 5-10 m and more may ensure the regulation capacity, which is sufficient in most cases for using the water-carrying pebbly horizons as underground reservoirs to regulate seasonally and for many years the flowing of that part of surface waters, which is not used yet.

Water-carrying horizons in pebbles are characterized by the high ability to absorb water, great area spreading and considerable total capacity (power). They give an opportunity to develop the broad network of highly productive chinks of vertical drainage and centralized water supply. Their debit may vary from tens up to 100-200 l/s and higher and draining effect may reach many tens and hundreds ha.

In irrigation sites, supplied with water and requiring ameliorative improvement of salinized lands, chinks in pebbles may ensure more economical decision of ameliorative task. The above-mentioned debit is possible in most cases, when the dynamic level decreases by 10-15 m and the depth of chinks is approximately 50-100 m.

Large diameters of drilling, simplifying the task of creating the powerful gravel-sand filter around chink strainer, finally will reduce considerably the specific cost of pumped out underground water.

3. CONCLUSION

In agricultural experience as a result of not regulated water use the surface throw of water directly from the irrigated lands reaches more than 30% of the total water intake into irrigation systems.

Therefore, it is necessary, first of all, to regulate well the water use. Now the filtration coefficient (K_0) is often used for calculation of horizontal drains. In many cases the filtration properties of watered soils are changed over the short distances horizontally and vertically from the thousandth parts of meter up to several meters per day. The capacity of water-carrying horizons reaches many tens and hundreds meters, and the flakiness of the last horizon impedes the vertical water exchange. It is almost impossible to give the filtration coefficient value with proper accuracy for these conditions with relatively limited number of initial parameters.

Usually only the initial mineralization of groundwater in the upper part of water-carrying horizon is taken as a principle in project studies, aimed to change the existing meliorative and hydrogeological situation. The dynamic process of groundwater mineralization and, as the main thing, the possibility of managing them is not taken into account. By this approach it is possible to cause the land salinization in the near future, having at first fresh water and applying non-washing irrigation regime.

Critical correlations between bed depth and mineralization of groundwater for project conditions should be defined in view of other factors. First of all the project depth down to groundwater should be defined, which will define in its turn both the permissible degree of mineralization and necessary rate for prophylactic washing. Finally the economical technical equipment for decreasing the level of groundwater should be taken into consideration, as it is limited for horizontal drainage.

Development of salinized lands with groundwater bedded in not deeply is usually carried out in complex with general washing and artificial drainage. Project washing water is defined usually by simple multiplication of total saline store, which is to be removed out of root stratum, to specific water consumption. This rate is sufficient only for regular water distribution over the area. If the water distribution over the area is not regular, the main water mass is filtered near the drains. As a result of it the main part of the land remains unwashed. In this case the potential of the permanent network, which is to support the level of groundwater at the depth of 1-2 m, should be taken into account. But it is possible enough, while washing, to close the groundwater with the surface washing waters. This leads both to decreasing manifold the productivity of drains and using the regulating capacity of soils in aeration zone and the time factors.

REFERENCES

Pankratov P.A. (1979). *K probleme hydrogeological – meliorativnogo obosnovaniya meropriyatii po ispolzovaniyu Vodnich resursov I meloraciya zemel Tajikistana*,Donish, Dushanbe,16-31.

Shermatov, N., Normatov, I., Petrov, G(2006). Modern water-energetic resources use problems and perspectives of Tajikistan on conditions of global non-stability climate. Proceeding of National seminar "*Rainwater Harvesting and water management*".11-12 November 2006,Nagpur, India. Pradeep K.Naik(Ed.). Institution of Engineers(India), pp.464-474.

Normatov, I.(2003) Regional experience in solving of water resources problems in Tajikistan. Transboundary water resources: Strategies for regional security and ecological stability. *NATO Science Series. IV. Earth and Environmental Sciences*. Vogtmann, H(Ed.), Springer, pp.55-72.

Mirsaidov, U.,Normatov, I., Shermatov, N.(2002). Ecological aspects of water resources management in Transboundary rivers of Central Asia. Proceeding of Intern.Conf., *WAPDEC*. 11-13 December 2002, New Delhi, India. Devi,R(Ed.).IWA publishing, pp.51-54.

Water resources of Tajikistan(2003). In: Normatov, I.(Ed.) SLR Omu, Dushanbe, 112pp.

Gargini, A(2000). Management of Groundwater resources in Vulnerable urban areas. In: Andah, K(Ed.) GRIFO Publishers, Perugia, 145-158.

National Human Development Report Tajikistan (2003). UNDP, Dushanbe, 71pp.