BIO Web of Conferences **230**, 02003 (2026) https://doi.org/10.1051/bioconf/202623002003
ICAAA 2026

Reuse of collector-drainage water from irrigated fields in agriculture in Kyrgyzstan

Dzhumagul Zhumaevna Kendirbaeva[1*], *Ainura* Ryskulovna Zhunusakunova[1], and *Azimkul* Asylbekovna Esekeeva[1]

[1]Kyrgyz National Agrarian University named K.I. Scriabin, Kyrgyzstan

Abstract. A technology for reusing drainage water in agriculture in Kyrgyzstan has been developed, providing additional freshwater supplies. Its implementation allows for the reuse of used water, which will reduce water consumption, waterlogging, and secondary soil salinization. The water intake structure collects drainage water from irrigated fields, from which an irrigation network is laid along the slope. The pond is an enclosed pit, surrounded by a dam, containing a water intake and a water storage structure. Air pumps are installed inside the pond, in the form of diverging beams on pipelines with a dead end. This will not only reduce the anthropogenic load on the environment, but also provide an additional influx of fresh water needed to return used water to agriculture.

1 Justification of the relevance of the problem

Every state in a market economy strives to maximize its potential for developing local resources. In Kyrgyzstan, intercommunal conflicts arise not so much from territorial disputes and ethnicity, but from moisture shortages in the agricultural sector, where moisture-requiring crops predominate. Therefore, the ecological and economic parameters of river waters have long attracted the close attention of global scientists, and their potential in Kyrgyzstan significantly exceeds that of wind, solar, and biomass energy. Its territory is part of the closed Central Asian basin, located in the interior regions of the continent, where the slopes of the ridges are dissected by river valleys and dry sais, and the mountainous relief has formed about 10 thousand branched river networks that form the hydrological basins of the Syr Darya, Amu Darya, Chu, Talas, Ili, Tarim, as well as the lakes Issyk-Kul and Chatyr-Kul [1] .

In Kyrgyzstan, despite the fact that more than 80% of the territory is occupied by mountain ranges, 61.5% of the population's main activity is agriculture, but obtaining consistently high agricultural yields is only possible with the help of irrigation. For this purpose, in areas suitable for irrigated agriculture using surface water and artesian wells,

* Coresponding author: jumaevna48@gmail.com

lakes and reservoirs, numerous collector-drainage systems (CDS) with a length of 5054.6 km have been laid, of which 2714.2 km are open and 2340.4 km are closed. Their construction, which began in 1960-1965, was aimed not only at obtaining high agricultural yields, but also at strengthening socio-political ties in Central Asia, especially to cover water shortages in Kazakhstan and Uzbekistan. This is due to the fact that in the Central Asian states, 40% of water resources are formed due to river runoff from Kyrgyzstan, the catchment area of which is 76.5% owned by the Aral Sea system with reserves (km2) of 2458, of which 47.23 comes from river runoff, 1745 from lakes and 650 from glaciers [2]. They partially penetrate to a depth of 30-50 to 200 m and again come to the surface in the form of springs with a flow rate of 1 to 10 l/sec, forming reserves of invaluable moisture and water reservoirs. On this basis, collector-drainage systems were laid initially along the main slope of the terrain, then in a combination of closed and open drains - perpendicular to the vertical ones. In the southwestern part of the region, a vertical drainage system with a length of 0.9 thousand km from 64 wells has been constructed, however, only 24 are in operation, while the horizontal system with a coverage area of 1,580.4 thousand hectares, which has become the main distribution system, stretches for 42.0 km and actively interacts with natural processes. Today, most open collectors are in poor condition, their bottoms are silted up and overgrown with reeds, which creates the conditions for the formation of gullies, while closed collectors often form erosion gullies and backwaters near their mouths due to the destruction of the mouth structures. An example is 19,200 hectares of agricultural land, which generates 243,000 cubic meters of collector-drainage water, accounting for 20% of its total volume. Of this, 13% comes from the Naryn River, the main waterway. Due to its fast current, the water in this river is fresh and clear, with suspended solids levels ranging from 36 to 137 mg/L at a pH of 7.8–8.0 and an oxidation state of 0.34–1.4 mg/L (Table 1).

Table 1. Return waters of the Kyrgyz Republic

River basins, lakes	Return water, % of water intake
Chu	43
Talas	35
Issyk-Kul	55
Syr Darya:	50
Chatkal	30
Kyzylsu	30
Naryn	30

The scientific and practical approach to reusing return water from irrigated fields has long been known, as scientists in many regions have concluded that the agricultural sector can develop without harming the environment through irrigation systems implemented using waste-free technologies. In this regard, the territory of our republic has long served as a permanent object of scientific and practical research, the results of which are widely covered in the works of A.N. Dikikh (1980), R.D. Zabirov (1962), B. Imankulov (1975–2017), M.I. Kaplinsky (1962–1980), B. Saipov (2000–2015) and others. In them, as the authors show, the areas of cultivation of agricultural crops, located in the altitude range from 400 to 3400 m above sea level, amount to more than 2.5 million hectares, of which 230–250 thousand hectares are highly efficient due to the use of modern technologies of mechanization, irrigation and selection.

The poor technical condition of the drainage and collector network, which prevents the required volume of water from being discharged after irrigation, is crucial. To address this issue, 50-60 km of the open network is regularly cleaned and 20-30 km of the closed network is flushed. In Central Asia, extensive experience has been accumulated in the utilization of drainage water for irrigation, among which the ion-exchange method of purifying it from inorganic compounds proposed by Russian scientists demonstrated complete demineralization with a dry residue of more than 5 g/l. The introduction of technology to increase return water in Kyrgyzstan is coming to the forefront of the agricultural sector due to the difficulty of attracting new and reformatting old lands due to the deep dissection of the relief and large differences in slope over short distances, as well as the activation of water and wind erosion, leading to lead to soil compaction and the removal of highly productive elements. Despite their centuries-old history, the mechanisms of their transformation remain poorly understood.

Undoubtedly, due to the impact of both water intake and discharge for irrigation, not only the quality of water resources but also the condition of irrigated lands deteriorates, since the inclusion of virgin soils in agricultural circulation without assessing their suitability leads to an increase in the volume and mineralization of collector-drainage waters. For example, drainage water from the Osh and Batken regions, which totals approximately 3 million cubic kilometers, pollutes rivers and lakes, as well as the atmosphere and soil. However, with appropriate treatment, it could become an additional source of irrigation water, which, in turn, would increase the region's water supply. Return water refers only to the portion of water that is fit for use and returned to irrigated areas. Of this total volume, a small portion (4.1–4.6 km^3) is used annually within the system, another portion is returned to rivers, and a third is discharged into low-lying areas.

Taking into account that at the global level the demand for water will grow in the coming decades, taking into account the widespread practice in the USA and Israel, Egypt and Algeria, Mexico and India of optimizing the flow of drainage water from the source of formation to its return to the environment, along with determining the irrigation rate from sowing to full ripening until the crops are fully ripe. a technology for their demineralization and reuse has been developed based on data from experimental tests, the starting points of which are an assessment of the chemical composition, as well as the creation of artificial reservoirs for drainage outside of irrigation systems.

2 Research Methodology

It is well known that drainage runoff is a negative consequence of the operation of collector and drainage systems. On the one hand, it pollutes surface water, and on the other, it serves as an additional source of irrigation water after special treatment. Since they contain increased mineralization due to pesticide and fertilizer residues, as well as heavy metals, their use is limited, and even with proper operation, treatment facilities are unable to bring purification to environmentally safe parameters due to land swamping and secondary soil salinization. Below is an improved methodology for drainage water supply ↔ maintaining soil water-air balance ↔ ensuring high-quality end products. Despite centuries of history, the mechanisms of water resource transformation and irrigated areas remain poorly understood.

The methodological principles are based on works covering the integrity of natural systems and issues of integrated use of surface waters, although an assessment of the conditions of their circulation associated with the quality of the biosphere and the technical condition of collector-drainage canals has not been fully considered [3]. Against this background, existing methods of purification and desalination of collector-drainage waters have shown that they can be divided into two groups. The first is based on the removal of contaminated components by technological and chemical-biological, as well as physicochemical methods, and the second – based on artificial reservoirs created outside irrigation systems, from which, using hydrate technology, clean water is separated with a pH of 6.8 to 7.5 and a dry residue of 1.0 to 1.5 g/l with a chemical and bacteriological composition, including suspended matter, and physical properties that meet sanitary standards. In Central Asia, extensive experience has been accumulated in the utilization of drainage water for irrigation, among which the ion-exchange method of purifying it from inorganic compounds has shown complete demineralization with a dry residue of more than 5 g/l [4]. To increase crop yields in Kyrgyzstan, algorithms for determining irrigation rates during the growing season have been proposed. These algorithms assume that moisture reserves at the beginning and end of the growing season depend on the amount of precipitation in winter, spring, and autumn, and at the end of the growing season, on the amount of precipitation in autumn [5]. To increase crop yields in Kyrgyzstan, irrigation rate algorithms have been proposed for the entire growing season. These algorithms assume that moisture reserves at the beginning of the growing season depend on the amount of precipitation in winter, spring, and autumn, and at the end of the growing season, on the amount of precipitation in autumn. This shows that the treatment of drainage water before and after irrigation of lands, as well as the regulation of its consumption, are extremely important in solving the problem of food security as a resource- and water-saving approach. This paper presents the results of our research obtained for the implementation of the reuse of drainage water collected after irrigation of fields, since the suitability of their quality is determined by the state of the biosphere, as well as by the technical indicators of collector and drainage canals [6].

The research methodology includes two stages: the first is the collection and analysis of actual monitoring observation materials, which will serve as a starting point for assessing our data, conducted to demineralize drainage water throughout the irrigated area before it enters the rivers. This is explained by the fact that only comfortable conditions, primarily free access to clean water and a healthy diet, ensure the sustainable development of life on Earth. To fully assess the current situation, all sources of wastewater flowing through various soil and geomorphological conditions were studied. Therefore, data on air temperature and humidity, rock properties and precipitation were additionally used not only in irrigated areas, but also in remote areas.

Thus, the upper reaches of rivers are characterized by a predominance of boulders, where the channels have sharp elevation changes, the magnitude of which is determined by the river's current velocity. The width, depth, and nature of the banks, as well as the sinuosity and composition of the channels, vary significantly in different sections of the same river. In our technology for the reuse of drainage water in agriculture, among the gases that form hydrates, namely, expensive freons - halogenated hydrocarbons that exist at temperatures up to 210^0 C, as well as methyl chloride (CH_3 Cl) and methyl bromide (CH_3 Br) at a pressure of no more than 1.6 kPa, which are harmful to the Earth's ozone layer, are excluded. In such conditions, chlorine for demineralization of drainage water, despite its toxicity, is of great interest, since it is easily soluble in water and has a high hydrate formation temperature (28.7^0C).

It's important to note that chlorine is widespread in nature, environmentally safe, and its aqueous solutions are non-toxic and do not require complete extraction from fresh water. When exposed to water at certain temperatures and pressures, chlorine forms a gas hydrate consisting of gas and fresh water, while the salts remain in solution.The second stage describes the reservoir's operating algorithm, based on the dual role of natural waters. This includes, firstly, the interconnectedness of all processes occurring over long geological periods, and, secondly, the ability to quickly respond to any anthropogenic impact [7]. .

Thus, the proposed technology ensures the reuse of drainage water suitable for agriculture.

3 Research Results

During an expedition to the Chuya Depression (Fig. 1), it was established that of the total length of the drainage and catchment network of 3,337 km, 1,551 km of the open network require major repairs, and 842 km, or 36% of the closed network, require flushing for restoration. The main reason for this is the slow movement of water. In addition, the level of the existing water resource management system oriented towards organic farming is low,

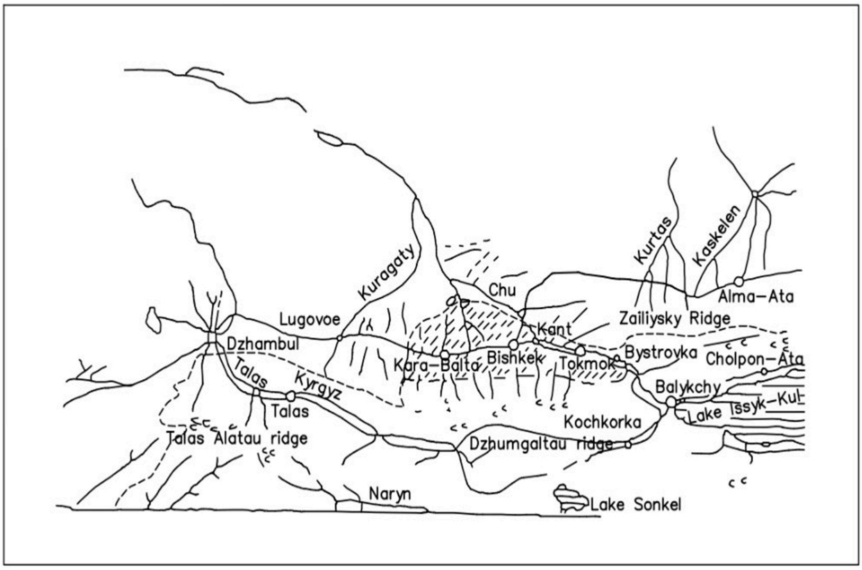

Fig. 1. Map of the location of administrative settlements in the Chui region

despite the absence of an environmental threat from the harmful effects of wastewater with a concentration of 3.0 to 5.7 g/dm³ and pesticides that have not reached the maximum level of negative impact on the human body.This is evidenced by the parameters of the territories, where 13.5 thousand hectares are marshy, 29.9 thousand hectares are saline, and 8.99 thousand hectares are both marshy and saline, which results from the discharge of untreated wastewater into irrigated areas, and this is also often a source of salts entering rivers and polluting water bodies.

A wastewater treatment technology for reuse has been developed, using a river with water-regulating devices and a storage tank as a receiving water source, from which a drainage network is laid. This technology ensures the recirculation of used water. Experimental tests on demineralization of water from collectors and drainage systems were conducted at 20 sites with complex chemical compositions—pH from 3 to 7 and solids content from 2 to 5 g/l—located 5-7 km apart. Here, an increase in mineralization and the volume of return of channel waters is observed, which is typical for all lower zones: thus, in the Chui region - in the Panfilovsky district - every second hectare of land, the third hectare in Zhailsky and Moskovsky, the fourth hectare in Sokuluksky are unfavorable due to a decrease in the yield of agricultural crops [8]. Taking into account the initial cycle, which includes the analysis of data for each section and the technical condition of the drainage network, the chemical composition of drainage waters along the Alamedin River, which flows from south to north through the Chtolitsy, varies from bicarbonate-sulfate calcium to sulfate-chloride sodium and calcium. Throughout its length, this river, receiving inflow from 46 collectors and 15 drainage canals, returns between 18 and 78 million cubic meters of water. Overall, for the Alamedin and Ala-Archa rivers, especially near the Chu River, as well as the city of Bishkek and the area where numerous industrial and livestock wastes are located. Most villages and highways are characterized by highly mineralized return waters. However, precipitation is uneven: in some areas, up to 1,500 mm of precipitation falls, while, for example, in the western Issyk-Kul Basin, only 100–150 mm is received, due to the mountainous protection afforded by the air currents coming from the west (Fig. 2).

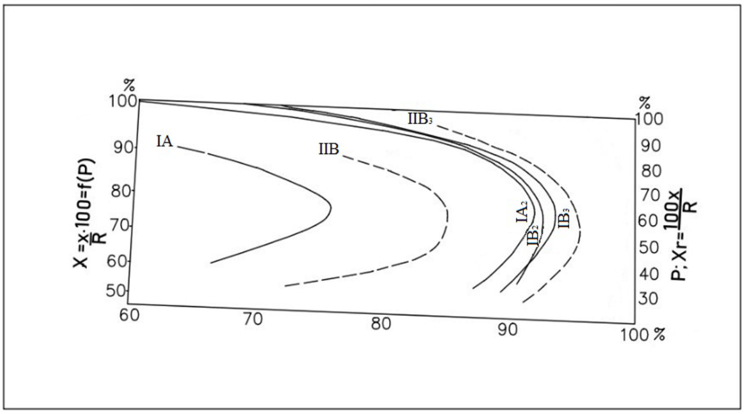

Fig. 2. Aerial photograph of precipitation distribution in the Alamedin region.

Positive results in agriculture can be achieved through the use of high-performance irrigation systems. To ensure their reliable operation, storage reservoirs have been proposed, in which drainage water is stored during the winter and then released onto irrigated fields in the summer. It is proposed for areas adjacent to irrigated fields, and its parameters are regulated by the wastewater inflow and the climatic conditions of the specific area. The storage reservoir is a pit with a water intake and a water inlet, and inside it, air pumps and diverging pipelines terminating in a dead end. Until the growing season, drainage water is accumulated in reservoirs with a capacity of up to four meters .

The wastewater treatment system, shown in the plan and section A-A, is presented in Fig. 3 and consists of a reservoir with pipelines, a pumping station, and a network of pipelines.

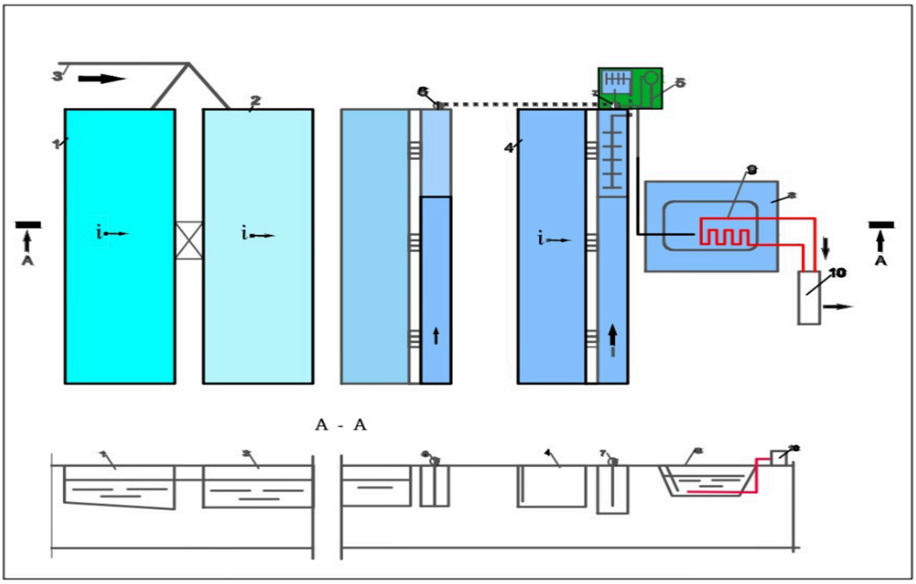

Fig. 3. Experimental flow chart of drainage water reuse technology in plan and section A-A: Legends: 1, 2 – drainage pipeline. 3 – drainage water. 4 – drainage water storage tank. 5 – drainage water treatment unit. 6, 7 – pumping units. 8 – tank. 9 – pipeline. 10 – desalinated water.

The implementation of this technology begins with the separation of the solid fraction, for storage of which a concrete platform is provided, as well as vertical settling tanks and other technical elements. entire volume of drainage water includes not only silt particles settling to the bottom of the reservoir, but also nitrogen, phosphorus, and potassium, which are essential for agricultural crops to meet environmental safety requirements in agronomy.

Water collected from irrigated fields (3) is discharged through pipes (1 and 2) installed above the bottom of the reservoir, ensuring free drainage and preventing overflow. This is facilitated by the absence of backflow due to its higher bulk density than pure water.

The preparation of drainage water for reuse for irrigation of agricultural lands is based on the operation of a storage reservoir (4), and in order to avoid evaporation processes, a closed type (5) is proposed, and to isolate from filtration into groundwater, the bottom is waterproof with a partition filled with sorbent granules.

The granules at the bottom not only cleanse the soil of pesticides and pollutants but also enrich it with calcium, thereby reducing its alkalinity. The proposed technology for reusing drainage water collected from irrigated fields can be applied in a wide variety of situations aimed at improving the hydrophysical properties of soils.

As designed, it protects the reservoirs from sediment and plankton, floating debris and oil products, thanks to a water collector with regulating devices (9), from which a network is designed that supplies drainage water through an open channel before diluting it with fresh water supplied by a pumping unit (6 and 7). In it (8), the pipes are made of asbestos cement, through which water passes through the lower openings, as well as an additional annular gap measuring 20 mm (10). For asbestos-cement pipes with a length of one section of 3-4 m, the water intake openings (d = 10 mm) are arranged in three rows of 33 openings per 1 m, and their diameter for a length of one section of 0.8-10 m is (d = 12 mm).

It should be noted that the backfill consists of an outer layer 10-12 cm thick, filled with coarse sand up to 5 mm in size, and an inner layer 10-12 cm thick, consisting of fine gravel ranging from 5 to 20 mm in size. The selected particle sizes and dissolved salt content of the drainage water are based on the practice of agricultural regions with arid climates. Thus, sediments (mm) ranging in size from 0.1 to 0.15 silt up drainage channels, particles between 0.1 and 0.005 mm improve the physical properties of soils and increase permeability, and particles smaller than 0.005 mm have nutritional value. Sediments similar in chemical composition to clays are dominated by silica, alumina, and humus, containing calcium and magnesium, sodium, and potassium salts.

The selected samples were subjected to physicochemical analysis, first each one separately for an individual assessment of the quality of the experiment, then, by mixing them in different volume ratios (10, 20, 30), a common flow was obtained for the objectivity of centralizing the cleaning processes using the same installation. Since chlorine levels in soil greater than 0.01% inhibit plant growth, its content in our diluted waters is up to 300 mg/dm³. The calcium/magnesium ratio (Ca/Mg) is also within acceptable limits, with calcium concentrations not exceeding 30.0 mg/dm³. Furthermore, the predominance of calcium over sodium and magnesium is beneficial.

According to our data, salt content reaches 0.10% (1 g/l), a level consistent with low irrigation rates and associated with precipitation. Spectral analysis of river, wastewater, and drainage water showed that dissolved nitrogen, phosphorus, and potassium, as shown in Table 2, are within the limits of suitability for land irrigation.

Table 2. Trace element content in river, wastewater, and drainage water, mg/dm^3

Elements in the soil	River water	Wastewater	Surface	Water bodies
Cobalt	0,004	0,027- 0,042	0,2	0,03
Manganese	0,008	0,061	1,0 1,0	0,01
Zinc	0,005	0,015	0,082	0,01
Molybdenum	0.0001-0.0002	0,08	0.05	0.0082

Irrigation water temperature also affects crop yields, so for heat-loving crops in Kyrgyzstan's high-mountain regions, it is proposed to warm glacial water in seasonal catchment basins. It has been found that as drainage water flows into irrigated areas, the deviation in river system parameters increases.

The calculation of the volume of dilution of drainage water in Kyrgyzstan with an arid climate was made using the formula of V.V. Kovda: K = Cm + Cm • Kd, where K is the coefficient of dilution of drainage water to 1.5 g / dm³, multiplied (K) by the irrigation rate; Cm is the salt content (3.02) in drainage water, g / dm³; Kd is the mineralization of the Alamedin River water (0.2), used for dilution, g / dm³.

The volume of water for dilution K = 3.02 + 3.02 • 0.2 = 3.712 is 1:3. The washed hydrate is then separated into fresh water and gas, ready for the next step. This technology is also suitable for tank flushing, and overflow protection units are included for safe operation, demonstrating the reliability of environmental protection devices.

The parameters of all reservoir components are designed for continuous operation, as well as for a groundwater level that is always below the discharge pipeline. These parameters can be used to characterize water inflow from irrigated fields under climate change.

According to the results of the climate change forecast presented in the Third National Communication of Kyrgyzstan, a slight increase and subsequent decrease in the maximum discharges of rivers in the lowland zone at the beginning of warming are indicated, but their practical constancy is allowed with a shift of the maximum to earlier dates in the lowland areas

4. Conclusion

In Kyrgyzstan, despite the fact that more than 80% of the territory is occupied by mountain ranges, 61.5% of the population's main activity is agriculture, but obtaining consistently high agricultural yields is only possible with the help of irrigation. An example is 19,200 hectares of agricultural land, which generates 243,000 cubic meters of collector-drainage water, accounting for 20% of its total volume.

Of this, 13% comes from the Naryn River, the main waterway. Of no small importance is the failure to take irrigation standards into account and the high groundwater level throughout the year, which, by accumulating about 1 million m^3 of irrigation water, not only covers its deficit, but also leads to waterlogging and salinization of territories in certain areas.

Precipitation is distributed unevenly across the study area, reaching 1,500 mm per year, but in the western part of the Issyk-Kul Basin, it ranges from 100–150 mm. This is due to the basin being protected on all sides by mountain ranges, and air inflow coming only from the west.

Reuse of drainage water is based on the operation of a collection pond. To prevent evaporation, a closed pond with a watertight bottom is proposed. It is designed as a two-section pit with an overflow partition, and is backfilled with granular sorbent to isolate it from seepage into groundwater.

To determine the cause of deviations in quantitative indicators in the river system as collector-drainage waters flow from the irrigated area, the volume of dilution of drainage waters with waters of the Alamedin River is 1:3, taking into account data characteristic of an arid climate.

A reliable technology for reusing drainage water in agriculture was achieved by creating a reservoir in which water is stored in winter and then released onto irrigated fields in summer.

Following a comprehensive assessment of the quality of collector-drainage water for its suitability for food safety requirements, it was proposed to monitor the technical condition of the storage tank and the technologies for the reuse of irrigation water, taking into account natural conditions leading to soil degradation and spontaneous depletion of water resources.

References

1. A.I. Mezhov Paths of Land Reclamation and Development in the Chui Valley. Kirgizdat, - 132P**.** (1961)
2. B. Imankulov, J. Zh Kendirbaeva. On the problem of protection and rational use of water resources of Kyrgyzstan. Hydrometeorology and ecology. No**. 1** (**40**) Alma-Ata. P. 98-103, 36452455_63067757 (2006)
3. D. Zh. Kendirbaeva, A.R.Zhunusakunova and K.A Sarygulova. Current State of Water Resources Use in the Central Asian States. Bulatov Readings. - Vol. **2.** Krasnodar. P. 78-81, 54126833_29987924 (2023)
4. .Kireycheva Prospects for the development of drainage in the Volga region. Land Reclamation and Water Management**.** No. **3,4.** P. 33-37. (2023)
5. J. Zh. Kendirbaeva, A. R. Zhunusakunova, K.A. Sarygulova Algorithms for determining the water consumption rate of agricultural crops during the growing season in Kyrgyzstan. Bulletin of the Altai State Agrarian University. No. **3 (221)**. Barnaul. P. 47-50, 50416807_42727944 (2023).
6. J. Zh Kendirbaeva Features of the formation and change of river runoff in Kyrgyzstan under natural and man-made conditions. The Fourth Vinogradov Readings: Hydrology from knowledge to worldview. A collection of papers. St. Petersburg. P. 669-674, 43309847_82130410 (2020).
7. Puzanov A.V., Baboshkina S.V., Rozhdestvenskaya T.A., Balykin S.N., Troshkova I.A. The content of microelements (Fe, Mn, Cu, Zn, Cd) in filtrates of mountain-forest dark gray soils of the northern Altai depending on changes in their water permeability //

International Journal of Applied and Fundamental Research. No. **3-2.** Barnaul. P. 227-232**.** (2015).
8. K.A.Sarygulova, D.Zh.Kendirbaeva and Sh.D Abdikulova. Technologies for rational use of water resources on the foothill plains of Northern Kyrgyzstanю. Bulletin of the Kyrgyz National Agrarian University named after K.I. Skryabin**.** No. **56.** Bishkek. P. 202-207, 82808471 (2024).