"Exploring the Potential for Collector-Drainage Water Reuse in Fodder Crop Farming: A Case Study in Uzbekistan's Mizachul Steppe"

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Abstract. The recycling of collector-drainage water (CDW) with high mineral content increases the salt levels in inland water bodies, which can limit the usability of the water downstream. To improve the agricultural irrigation system and livestock production in Central Asia, comprehensive quantitative and qualitative research is needed to analyze the inter-annual and multiyear CDW generation patterns. A Ph.D. research study has been designed to investigate the amount, quality, and ionic composition of CDW and its reuse potential for maize crops in the Mirzachul steppe of Uzbekistan. Reusing drainage water is an effective approach to supplementing water resources and reducing drainage disposal problems by reducing the volume of water involved. Reusing drainage water for irrigation can also mitigate water pollution issues. Different reuse methods include conventional agriculture, salt-tolerant crop cultivation, wildlife habitats and wetlands, and initial reclamation of salt-affected lands. In recent years, salinity levels in all major CDWs have shown a continuous increase. The present study is based on scientific research that involved proper fieldwork monitoring and observation while irrigating maize crops with a mixture of salt water and fresh water.

1 Introduction

In the past 60 years, global consumption of drinking water has increased by more than eightfold [1]. This trend has led many nations to face water shortages, forcing them to resort to importing water. As water is a scarce resource, its availability is increasingly becoming a cause of conflict and a driving force behind geopolitical issues around the world. The rapid growth of water consumption is contributing to a global water crisis, and developing new sources of water requires significant investment in water management systems. As the cost of water increases, each cubic meter of water will become more expensive, making it increasingly challenging for developing countries to access water and exacerbating the problem.

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Due to this central role in food security and socio-economic welfare, water quality is an increasingly global concern: both environmental conditions and human well-being are dependent on water quality [2]. The quality of water resources is continuously changing, largely a reason behind human-induced sources of change, such as eutrophication, secondary salinization, sedimentation, microbial pollution, and toxic point sources. Some studies have proven that general salinity hazards, calcium, carbonate acid, sodium alkalization hazard, the danger of magnesium alkalization, and the hazard of chloride salinization are the main contaminants of water resources. These pollutants significantly deteriorate the water quality around the world. Ongoing quantitative decrease and qualitative deterioration of water resources on our planet have gradually increased the risk of fresh and clean water shortage for all purposes in our society. In order to reduce the negative impact of these changes on human society, it is necessary to develop proper monitoring and management of water quantity and quality, which, in turn, based on reliable scientific results.

Currently, according to the Decree of the President of the Republic of Uzbekistan "On measures for the effective use of land and water resources in agriculture" dated June 17, 2019, No. PF-5742 for use in 2020-2030. Irrigation and land reclamation measures will be carried out on an area of 1,117,723 hectares [3].

In 2019, 42 134.2 tons of salts were received with irrigation water into irrigated land. 52 278.7 tons of salts were discharged through collector and drainage networks [8]. 4,300,000 hectares of irrigated land in the country, 46 percent of the area is saline. In 2019, the ameliorative condition of 303,000 hectares of land was improved, by maintaining the groundwater level and increasing the efficiency of land reclamation, the share of saline areas decreased by 45.7% [4].

Approximately 92% of the water resources utilized by the Republic of Uzbekistan, which amounts to 54-55 cubic kilometers (km3), is used for irrigated agriculture. Over 20-22 km3 of mineralized (3-4 g/l) collector-drainage waters formed in some of the irrigated regions of the Republic of Uzbekistan. Under existing conditions of water scarcity, farmers can reuse the collector-drainage water for irrigation and leaching [4]. The world's population growth is reaching such a level that quality water is insufficient for basic human needs, including irrigation of agricultural lands.

When facing a scarcity of irrigation water, reusing drainage water is an essential strategy to supplement water resources. Reuse can also ease drainage disposal issues by reducing the volume of water involved. Repurposing drainage water for irrigation can help to mitigate water pollution issues. Reuse can be done in various ways, including conventional agriculture, growing salt-tolerant crops, creating wildlife habitats and wetlands, and reclaiming salt-affected lands through reuse [5].

Typically, drainage water is of lower quality than the original irrigation water. Therefore, management measures must be taken to minimize both short-term and long-term negative effects on crop production, soil productivity, and water quality at the project or basin level. When dealing with highly saline drainage water, it cannot be used for crops that are sensitive to salt, but it can be used for salt-tolerant crops, trees, shrubs, and fodder crops.

Collector-drainage waters (CDW) are a big problem for Central Asia, and using CDW's are given some opportunities to improve water sectors and agriculture. Mirzachul steppe is one of the largest and most important steppes in Uzbekistan

2 Materials and methods

The Mirzachul Steppe is one of the significant regions for domestic cotton cultivation in Central Asia. This area encompasses the irrigated lands of the Syrdarya and Jizzakh regions of Uzbekistan (471.2 thousand hectares), the Chimkent region of Kazakhstan (122.4 thousand hectares), and the Khojent region of Tajikistan (14.2 thousand hectares). From 1960 to 1980 of the last century in the Mirzacho'l Steppe, which has large land reserves, irrigation, and reclamation construction developed at a high rate. Extensive areas of uncultivated land were converted to irrigated land, leading to the expansion of the irrigation zone to over 600,000 hectares. [4,6]. The production of agricultural goods saw an annual increase. Nevertheless, alongside these positive developments, there were adverse consequences, and the irrigated soils underwent evolutionary changes. The condition of the soil reclamation and ecological state of the irrigated lands had significantly worsened. The mineralized groundwater level had exceeded the "critical" level, and this had resulted in a heightened intensity of the secondary salinization and desertification processes. Currently, an increase in secondary salinization has a serious impact on food security due to the unregulated use of CDW.

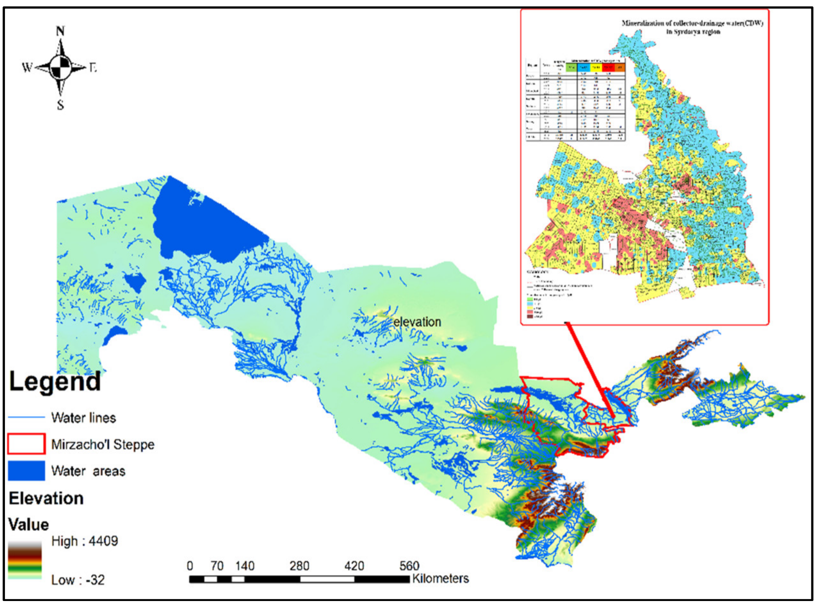

Fig. 1. Represents the boundary Mirzachul steppe and the research area (Syrdarya regions, Collector-drainage waters).

Assessment of Collector-drainage water reuse potential for livestock crops in Agriculture (Maize crop) in Mirzachul steppe variety of different datasets; own field and laboratory measurements used for this research. For studying and examining the climatic, land use, and surface water changes in the Central Asian regions, the datasets will be provided in Table 1 have been considered which will be updated with further research progress.

To investigate the long-term water contamination dynamics of rivers and colletor-drainage systems, historical data regarding the mineralization contents as such, sodium (Na), calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorus (P), and Microbiological and parasitological indicators will be collected at the Hydro-meteorological Research Institute of Uzbekistan, the Ministry of water resources of the Republic of Uzbekistan, and the State Specialized Inspection of Analytical Control of Uzbekistan. The Uzbek Hydrometeorological Service is analyzing the water quality of all Rivers in Uzbekistan on a monthly basis using well-established laboratory analytical methods (flame atomic absorption spectrometry and ion chromatography), as well as traditional titrimetric and electrochemical methods. Collector-drainage systems and waters are monitored by the department of land reclamation expedition in the Ministry of water resources of the Republic of Uzbekistan. We plan also to use the YSI portable multi-parameter instrument and analytical test kits for express analyses of some water quality indicators on the field.

River water will be sampled at several points, reflecting the most typical characteristics of the upper, middle, and lower currents of the river to determine the investigated substances. After that, we study the dependence of irrigation water on CDW's. It is necessary to know how much-mineralized water comes with irrigated water (river and canals), and how much leaves the irrigated field by collector-drainage systems. These informations will be taken from the Hydro-meteorological Research Institute of Uzbekistan, and the Ministry of water resources of the Republic of Uzbekistan.

Table 1. Datasets summary used in the research.

	Purpose	**Date (from-to)**	**Resolution**	**Type of sources**	**Date sources**
Meteorological and climatological analysis	Study data on the average monthly, decade, and dearly air temperature, wind, radiation, absolute humidity, solar radiation, and precipitation from a nearby weather station.	3 periods. for example: 1.2008-2010 2.2014-2016 3.2021-2023	Monthly, Decade, Dearly	copy from annual reports	UzHydromed Centre. **http://www.meteo.infospace.ru**
Water quantity and its quality (main cannels in region)	To study justification of formation water resources, and water quality in relation to water consumption	3 periods. for example: 1.2008-2010 2.2014-2016 3.2021-2023	Monthly, Decade	copy from annual reports. Analyzed sources.	UzHydromed Centre. **http://www.cawater-info.net**
CDW quantity and its quality (main collector-drainage system in region)	To study justification of formation water resources, and water quality in relation to water consumption	3 periods. for example: 1.2008-2010 2.2014-2016 3.2021-2023	Monthly, Decade	copy from annual reports	Ministry of Water Resources of the Republic of Uzbekistan. Land reclamation expedition at the Regional Branch
GIS	For NDVI and make a map Cannels and CDW				**https://earthexplorer.usgs.gov/**
CropWAT, CLIMWATt	to determine the irrigation regime of maize crops			Application 8.0 version	**https://www.fao.org/land-water/databases-and-software/cropwat/en/**

The determination of the salinity level will be performed by using specialist instruments such as conductometers, as well as using traditional gravimetric methods and chloride ions will be determined by the Mohr method. Statistical analysis will be conducted in the R software, and GIS technologies will be used to map the water quality and location of the main pollution sources of the River against different criteria during research. The water quality indicators will be calculated to evaluate the quality of the chosen river and collector-drainage systems.

Irrigation experiments are carried out according to the method proposed by the scientists of the Central Asian Research Institute of Irrigation (SANIIRI). Changes in the soil conditions of the field are analyzed by the methods of scientists from the Uzbekistan research institute of cotton (UzPITI).

Average climatic data (maximum and minimum temperature, humidity, wind speed, and sunshine hours) on monthly basis will be collected from Sirdaryo(Gulistan), a meteorological observatory station.

3 Results and discussion

Like many other peoples of the world, our people fondly call Mother Earth, and the farmer is the breadwinner. Agriculture is currently the largest consumer of water resources.

In Egypt, there is practically no rainfall, agricultural lands are irrigated, in the UK, it provides moisture to almost all agriculture due to rainfall, and, in the USA, agricultural lands are irrigated, mainly in the western part of the USA[8]. At present, about 30 million hectares of land are used in the national economy of the Republic. This is about two-thirds of the total territory of the Republic. 95% of land and water resources and 85% of water resources are in agricultural turnover. Of this, irrigated land is only 15 percent, or 4.3 million hectares[4].

The rapid pace of population growth in Uzbekistan requires an increase in agricultural production. But the successful solution to this issue in the conditions of our country is always based on the lack of water resources (irrigation water) because 80% of water resources come from transboundary rivers. Artificial regulation of the flow of transboundary rivers has led to the fact that today on vast areas of irrigated lands in Uzbekistan there is a shortage of water resources during the growing season (vegetation), which again forces us to look for other non-traditional sources of irrigation. A number of measures are currently being taken to ensure the sustainability of water supply to irrigated lands.

Semi-arid regions, which are found in the Americas, Oceania, Asia, and Africa, constitute around 30% of the global terrestrial area. Uzbekistan and Central Asia are also categorized as semi-arid regions.

Water is an essential requirement for sustaining life on Earth and plays a crucial role in nearly all biological processes. In addition, water serves multiple functions in the climate system, influencing the Earth's temperature, weather patterns, and atmospheric conditions[9]. Most organisms on Earth are composed of a significant amount of water, typically ranging from 50% to 90% of their total mass. Aquatic organisms, in particular, can have a water content as high as 99%[10]. Water also is an important role in plant life. Water makes up 75-90% of the plant organism and 98% of some organs[11]. The seed of a plant in soil, depending on its type, origin, and size, must drink a certain amount of water in order to germinate. For the growth of maize seeds, 90% of water is required in relation to the weight of dry air seeds. Plant cells can develop normally only when they are sufficiently saturated with water, as a result of which the rest of the vital activity is spent on the formation of some complex organic substances in the process of photosynthesis.

Water plays a crucial role in the growth and development of plants. When water enters the plant cell, it causes the volume of the cell to increase, exerting pressure on the cell membrane and maintaining the stressed state of the cell and tissue. Water also carries various nutrients from the soil into the plant, which are transported to the leaves and other organs. Photosynthesis, the process of producing organic matter, cannot occur without water. The significance of water for cotton production cannot be overstated. Complex physiological and biochemical processes in the plant organism manifest themselves through the water. Naturally, the optimal course of the whole chain reaction of these processes also depends on the feeding of the goose, and also irrigation. Scientists say that water is a plant's deposit. Water is involved in photosynthesis, providing water for plant assimilation of nitrogen, phosphorus, potassium, and other macro-micro elements in the soil. Water regulates the temperature in the plant body[11]. Simultaneously, Soil-water salinity is a condition that occurs when salts accumulate in the soil due to water uptake by plants and evaporation at the soil surface. This condition is not permanent and can be mitigated by dilution from subsequent irrigation or rainfall, leaching to subsurface drains, or percolation below the root zone. However, in areas with shallow water tables and fine-textured soils, salinization can continue to occur through capillary rise from the saline water table. The use of saline water for irrigation, coupled with poor fertilizer and irrigation management, can also increase the risk of salinization[12]. Efforts to improve water use efficiency should focus on reducing leaf transpiration by controlling stomata, which regulate leaf gas exchange and transpiration. Studies have shown that stomata can directly respond to changes in soil water availability by adjusting their opening. This suggests that managing soil water content can help optimize stomatal behavior and improve plant water use efficiency[13]. Research has shown that using alternate furrow irrigation (AFI) can lead to higher numbers of primary root initiation and increased root biomass in the soil compared to fixed furrow irrigation (FFI) or conventional furrow irrigation (CFI) treatments. In addition, deficit irrigation where the water quantity is halved (to 157.5 mm) resulted in less primary root initiation and root biomass accumulation in the FFI and CFI treatments but had smaller differences when using the AFI system [15].

Decreased transpiration rate due to lack of water leads to disruption of the normal course of physiological processes in the leaves. As a result, there is a sharp rise in temperature of the leaves, disruption of protoplasms in the colloidal system, failure to carry out photosynthesis, difficulty breathing.

Water is a vital element for the growth and development of plants, and its balance is crucial for plant survival. If the amount of water absorbed by the roots is insufficient to cover the amount of water that evaporates through the leaves, the plant's growth and yield will be negatively affected. On the other hand, excess moisture in the soil can reduce the amount of oxygen available to the roots, hindering their normal development. Therefore, water management is a critical aspect of agricultural crop irrigation.

Establishing the appropriate lower limit of soil moisture before irrigation is a crucial factor in ensuring optimal plant growth. This is because plants require different amounts of water at different stages of development, and irrigation should be carried out based on the specific soil conditions at each stage.

Durdiev N.X., Mambetnazarov A.B., Masharipov A.A., Mashrapov X., Usmonov S., Khudarganov K., indicators of total moisture content and the amount of bound free water in plant cells were used to describe the plant water regime [15].

Soil moisture content and dynamics in particular play a critical role in influencing many hydrological processes relevant to the root zone, such as the separation of precipitation into infiltration and runoff and the separation of net radiation into sensible and latent heat fluxes. Proper knowledge of the processes that control soil water dynamics proves essential to achieve this target. Hydrological models can thus play a crucial role in the understanding of the dynamic interactions among climate, soil, water, and vegetation, with relevant implications for agriculture.

According to S. Mamatov and Kh.Umarov "In settlements, a huge of generated waste waters, its discharge is more than 2.46 million m3/day. All this water is discharged to its natural depth and evaporates."[14]. In the conditions of Uzbekistan, these waters may well become an additional source for irrigation, that is, their use for irrigation can contribute to covering the deficit of irrigation water during the growing season.

J. Shodmonov, S. Isaev, it is emphasizing that the main criterion for the use of drainage water for irrigation is to prevent the risk of re-salinization of irrigated soils. The high salt content in the water used for irrigation leads to an increase in the salinity of the soil solution. Therefore, when using drainage water for irrigation, the salinity rates depend on the water-physical and chemical properties of the soils of the irrigated area. According to Shodmanov and Isaev, irrigation water consists of 70 % fresh water, its mineralization with more 1 g/l, and collector-drainage waters 30%, its mineralization not more than 4 g/l. it is possible use for irrigation. The most optimal solution is the use of CDW mixed with fresh river water for irrigation during a period of shortage of water resources [15].

K. Mirzazhonov, assuming that in the crop rotation system, the average yield of cotton when irrigated with collector water containing 2.5–3.5 g/l of salt was 3.33 t/ha. In the Syrdarya region, where cotton is irrigated with salt water, the crop rotation has been beneficial, but by the fourth year the yield will decline [16].

Pakistan faces several challenges in agriculture production, and salinity is one of the major issues identified by Pakistani scientists. To combat this problem, canal water is used in a cyclic manner to leach out salts that accumulate during irrigation with saline water, preventing salt accumulation from exceeding the crop's tolerance level. Researchers conducted pre and post-harvest soil analysis to assess physical and chemical characteristics and noted the growth and yield components of maize, including fodder biomass, plant height, diameter, and density. Their findings suggest that using saline water as a source of irrigation negatively affects the growth and yield components of maize[17], but mixing approaches to gave good results.

According to China's scientist's The importance of kernel weight in hybrid maize production cannot be overstated, as it is a crucial factor in ensuring seed vigor. In arid regions, irrigation is vital for maintaining kernel weight and overall crop yield. The KW-water model, which combines the Jensen model with biomass characteristic parameters, has been successful in predicting KW under different irrigation treatments. This model takes into account the source-sink relationship and can be used as a quantitative method for modeling KW in hybrid maize seed production. This research has important implications for farmers in arid and semi-arid regions, as it may allow for the use of saltwater irrigation in these areas.

The use of groundwater by plants has been studied in detail, according to which groundwater at a depth of 1 m increases the total water requirements of 1-year-old alfalfa by 73-80%, at a depth of 2 m - 30% and at a depth of 3 m. And 11-22%. It was found that in areas where groundwater is at a depth of 1 m, winter wheat meets 20% of its water needs in the initial stage of development and 50% in subsequent phases of growth from groundwater. He also noted that when the groundwater is located at a depth of 3.5 m, agricultural crops cannot use them at all.

A literature review shows that scientists have done a lot of scientific work in the field of agricultural crops irrigation. However, the salinity of collector-drainage waters during irrigation of agricultural crops has not been comprehensively determined. Scientific work on the use of complex methods in irrigated agriculture has been insufficiently studied. That is, water-food-food-natural resources are not considered together. And there are not enough materials for irrigation with collector-drainage water for maize crop in our conditions.

In saline soils, collector-drainage waters can have different mineralization. On irrigated lands, collector-drainage waters are one of the main sources of surface water pollution[3].

Water for irrigation can be divided into 5 groups according to the number of salts in it[13,18,19].

1. Mineralization up to 1 g/l - fresh.
2. The amount of salt is 1-3 g/l - weak.
3. The amount of salt is 3-10 g/l - average.
4. The amount of salt is 10-50 g/l - strong.
5. The amount of salt is 50 g/l or more - namakob

Scientists from the USA Ayers and Westcot proposed the following classification (Table 2).

According to the US classification, 3 g/L is good and 6 g/L is satisfactory. Irrigation water with a salinity of 5-6 g/l is widely used in many countries of the world - the USA, Tunisia, Algeria, Iran and others.

Table 2. Interpretive guidelines for assessing the combined effect of SAR and EC in irrigation water on soil infiltration problems[1].

SAR	**Degree of impact of SAR according to EC**		
	None	**Slight to moderate**	**Severe**
(mmolc/L)0.5	**dS/m**		
0-3	>0.7	0.7-0.2	<0.2
3-6	>1.2	1.2-0.3	<0.3
6-12	>1.9	1.9-0.5	<0.5
12-20	>2.9	2.9-1.3	<1.3
20-40	>5.0	5.0-2.9	<2.9

The possibility of using mineralized collector-drainage waters has been studied in detail at several experimental stations (Fergana, Bukhara, Khorezm). Some data have shown that collector-drainage waters have a detrimental effect on soil and vegetation. Some admit that positive results can be achieved. Factors such as the biological properties of the crop and its resistance to salt, the water-physical properties of the soil and the degree of drainage, water salinity and salt content have a strong influence on the efficiency of using saline water[19].

The amount of mineralized water used in Uzbekistan is directly related to the level of water supply in the year. In the Syrdarya region, drainage water with a mineralization of 1.39 (chlorine - 0.16) g/l is used to irrigate almost 3000 hectares of land in excess of 2.5 km3 per year[3].

In dry years, the water from the collectors can be used to irrigate cotton and flush with brine. At the same time, the permissible level of water mineralization on light and medium sandy soils with mineralization is 3-4 g/l, chloride ions - up to 0.5 g/l. In heavy sandy loam and loamy soils, 2.0-2.5 and 0.5 g/l of chlorine ion are recommended, respectively.

Table 3. Permissible mineralization of water when irrigating cotton.

Soil-lend reclamation condition	**Fixed mineralization, g/l**	
	Mineralization	Chlorine
Heavy, poorly permeable and poorly drained, near groundwater (Up to 1.5 m)	1.53	0.15-0.20
Moderately permeable and drained. groundwater at a depth of 1.5-3 m	3-4	0.40-0.50
Light (sandy loam and loamy), well-drained. groundwater at a depth of 3-4 m	5-6	0.70-0.80

When using collector and drainage waters, it is important to know the permissible amount of salts in them. At the same time, factors such as the amount and composition of salts in the water, soil properties and the reclamation state of irrigated lands should be taken into account.

The soil has good water permeability and water permeability, and in places where the groundwater is deep, the permissible amount of salts in the water is large. Alkaline (Na2CO3) salt water is considered unsuitable for irrigation. The use of water rich in sodium cations is also impractical, as it leads to soil salinity. The chemical composition of collector-drainage waters in Uzbekistan has been studied, divided into good, satisfactory, unsatisfactory, generally unsuitable categories of water quality and recommendations for the conditions of their use [21].

Summarizing the set of scientific data, it can be seen that the permissible levels of water salinity during irrigation of cotton in different ameliorative soil conditions are different (Table 3). After use on saline soils with water with mineralization up to 6 g/l. the rate of flushing with saline is increased by 35-40 percent. When using mineralized water for irrigation, the salts contained in it in the early stages have a certain negative effect on the plant. To ensure the density of seedlings on irrigated lands, the seeding rate should be slightly higher than when irrigated with river water[2].

The potential for the use of collector water in Uzbekistan is huge: only in Sarisuv, Yazyovan and Northern Baghdad collectors in Central Fergana the water consumption sometimes reaches 10-50 m3/s, and in the collectors of Northern and Southern Bukhara 10-15 m3/s. Thus, the widespread use of collector-drainage water in the irrigation of crops, along with the increase of water resources, creates a favorable ground for the development of new lands and the improvement of their water supply[3].

Assessing the appropriateness of irrigation water is crucial to avoid negative impacts on crop yield, soil salinization, product quality, and water supply stability. The chemical analysis of water is conducted while considering the area's climate and soil reclamation conditions to determine the suitability of using CDW for irrigation in the Mirzachul steppe. The main collector and drainage system of the region are analyzed and evaluated using a comprehensive approach[46].

The use of irrigation water from CDWs should not result in soil salinity, alkalinity, or hinder plant growth and yield. It is important to choose salt-tolerant crops for such irrigation. Evaluating the chemical composition of water and considering local climatic and soil conditions are crucial in determining the suitability of CDWs for irrigation[4]. The suitability of water for irrigation depends on the type of plants, the type of soil, their drainage, the ratio of cations and anions in the water.

Soil salinization during irrigation with Agricultural run-off waters is prevented by irrigation and drainage and agronomic methods. The selection of crops is determined by the sanitary requirements for the products obtained, the supply regime and composition of wastewater, soil reclamation conditions, as well as the existing specialization and direction of agricultural production.

However, experiments show that in the process of using wastewater, negative consequences are possible, affecting, in particular, the quality of groundwater. To prevent groundwater pollution, it is necessary to strictly adhere to the irrigation regime, irrigation technique, operational requirements, as well as the presence of drainage.[5]

Thus, when planning the use of wastewater for irrigation, one can be guided by the following groups of criteria:

A) reclamation criteria, according to which deterioration of the reclamation state of the irrigated area is not allowed;

B) agrochemical criteria, according to which a decrease in fertility and deterioration of the soil quality of an irrigated area is not allowed;

C) agro-economic criteria, according to which a decrease in the yield of cultivated crops is not allowed;

D) environmental criteria, according to which pollution of the environment, in particular ground and surface waters, is not allowed;

E) sanitary criteria, according to which safe working conditions for agricultural workers involved in growing crops on an irrigated area are ensured.

The quality of CDW's used for irrigation is primarily characterized by the following indicators:

- the sum of salt ions dissolved in water;
- the amount of sodium ions;
- the amount of chlorine ions;
- the amount of magnesium salts;
- the presence of soda;
- the chemical composition of dissolved salts.

The evaluation of wastewater quality is determined based on the overall salt content and the proportion of chemical components present, with a focus on the potential risk of salinization, alkalinization, and toxicity of the individual ions. High salt levels in irrigation water can lead to an increase in soil solution mineralization. The most important equations and indicators are given in Table 4.

Table 4. Basic equations for assessing the quality indicators of CDW (in complex methods).

Mains	Equation	Definition	Sources
In order to prevent the danger of soil salinization, it is necessary to assess the suitability of water for irrigation using the equation:	$K_{0.3} = \frac{0,03 \cdot M}{Ca^{2+} + Mg^{2+}}$	M – mineralization water mg/l; Ko.з < 4 - the water is suitable for irrigation of any soil; Ko.з = 4÷5 water is suitable for irrigation of sandy loam soils; Ko.з = 5÷6 water is suitable for irrigation of sandy soils;	Chembarisov E I 1996 Hydrochemistry of river, collector, and drainage waters in the Aral Sea basin The Aral Sea Basin (Springer) pp 115–20[6]
To assess the quality of CDW is to establish the degree of hazard of alkalinization by the sodium adsorption ratio (SAR):	$SAR = \frac{Na}{\sqrt{\frac{(Ca+Mg)}{2}}}$	AR value: 0-10 – (low Na water) little danger; 10-18 – (medium Na water) Soil texture and sodium sensitivity can pose challenges under conditions of low leaching. To avoid issues, soil should be permeable. When using water with a high sodium content (18-26), most soils may experience problems. The solution is to use salt-tolerant plants and adopt special management techniques, like using	Sposito, G., & Mattigod, S. V. (1977). On the chemical foundation of the sodium adsorption ratio. Soil Science Society of America Journal, 41(2), 323-329[7]. Chembarisov I. Elmir; Xodjimuratova T. Roza; Mirzaqobulov B. Jakhongirmirzo 2018 FEATURES OF HYDROLOGICAL AND HYDROCHEMICAL MONITORING OF SURFACE WATER OF THE KASHKADARYA REGION (Tashkent, Uzbekistan)[8]

		gypsum. In cases of very high sodium content (>26), satisfaction is unlikely unless the salinity is high (>2.0 ms/m), calcium levels are high, and gypsum is used.	
Evaluation of the suitability of CDW's for irrigation by sodium alkalinization must be carried out according to the dependence	$K_{Na} = \frac{Na^{+} + Ca^{2+} + Mg^{2+}}{Ca^{2+} + Mg^{2+}}$	KNa> 4, alkalinization is possible during irrigation of medium and heavy loams. KNa> 3 ÷ 5, alkalinization is possible with irrigation of light loams and sandy loams.	Shirokova Y I and Morozov A N 2008 About ways for improvement of water use in irrigation of Uzbekistan Adaptive and Integrated Water Management (Springer) pp 357–79 [9] Chembarisov E I 1996 Hydrochemistry of river, collector, and drainage waters in the Aral Sea basin The Aral Sea Basin (Springer) pp 115–20[6]
The criterion for the suitability of CDW's for irrigation is the absence it of the danger of magnesium alkalinization of the soil	$K_{Mg} = \frac{Mg^{2+} \cdot 100\,\%}{Ca^{2+} + Mg^{2+}}$	KMg > 50% magnesium alkalinization appears.	Reznikov, A. A. (2013). Methods of analysis of natural waters. Ripol Classic[10]. Chembarisov E.I. 2019 Hydroecological monitoring of river water quality in the Amudarya river basin within Uzbekistan Ecol. Constr.[8]
The suitability of CDW's for irrigation in Uzbekistan is the absence of the hazard of chloride salinization in water	$K_{Cl} = Cl^{-} + 0{,}5 \cdot SO_4^{2-}$	KCl = 3 ÷ 7 mmol/l, soils with low permeability can be irrigated; at KCl = 15 ÷ 20 it is possible to irrigate soils only with good water permeability.	Sobitjon Mamatov 2011 SUITABILITY CRITERIA FOR WASTE WATER IRRIGATION OF AGRICULTURAL CROPS Urgent Probl. WATER Manag. Reclam. Irrig. LANDS 319 64–70[11]. Chembarisov E I, Rakhimova M N and Mirzakobulov Z B 2019 LAND RECLAIMING CHARACTERISTICS OF COLLECTOR-DRAINAGE WATER

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			IN THE SYRDARYA REGION OF UZBEKISTAN Ways to Improv. Effic. Irrig. Agric. 54–9[12].

The evaluation of CDW's appropriateness for irrigation should be based on its chemical composition, including the concentration of dissolved minerals and the ratio of monovalent to divalent cations. Other factors, such as pH, levels of basic nutrients (nitrogen, phosphorus, potassium), trace elements, and specific substances, should also be considered. The natural conditions of the site, irrigation practices, and the characteristics of the crops being grown must also be taken into account when assessing the chemical composition of CDW. According to Ilina S.M., 2014, the activity of hydrogen ions in CDW’s should be in the range of 6.0-8.5, differentiated, taking into account the pH of the soil[9]:

< 6.0 - pH of irrigation water 6.5 - 8.5;

> 8.0 - pH of irrigation water 6.0 - 7.5.

Accoriding to, Shirokova Y.I., 2008, The use of irrigation (waste) water containing toxic salts should not cause an increase in the critical concentration of water-soluble salts in the soil, which is 0.1% for soils with annual salinization and 0.25% for soils with seasonal salinization, specifically for sulfate and chloride types of salinization[13].

Taking into account the granulometric composition of irrigated soils, the maximum concentration of the sum of salts in wastewater should not exceed:

with heavy and medium loamy soil composition - 1 g/l (15 mg eq/l),

light loamy - 2 g/l (30 mg eq/l),

sandy loam and sandy - 3 g/l (45 mg eq/l).

The suitability of water for irrigation based on an assessment of the salt composition of irrigation water, taking into account the irrigation rate used by plants of atmospheric precipitation, grain size distribution and water-physical properties of soils (by the value of the smallest moisture capacity of a 50-centimeter soil layer) can also be determined by the dependence[11][14]:

$$\frac{C\,VN_{50}\,M}{K_{2000}(M+P)} \leq 1 \qquad (1)$$

C - total content of toxic salts excluding calcium sulfate and salts, containing ions K, NH_4^+ and PO_4^{3-}mg-ekv/l

NV50 - the smallest soil moisture capacity of the layer 0-50 cm, mm;

M - average long-term weighted average irrigation rate by crop rotation, mm;

K2000 = 2000 - coefficient taking into account NV50 of heavy loamy soils (200 mm) and permissible concentration of the sum of toxic salts of 10 mg-eqv/l (0.7 g/l) in arid conditions, mm mg-eq/l;

P - average annual precipitation used by plants, mm.

The permissible content of biogenic elements (nitrogen, phosphorus, and potassium) in CDW's, when used for irrigation, is determined depending on the amount of their application with an irrigation rate and should not exceed the removal of these elements by the planned harvest, taking into account all types of losses.

With irrigation due to the deficit of water consumption, the permissible concentration of nitrogen, phosphorus and potassium in irrigation water is determined by the formula:

$$C_{NPK} = \frac{100B}{Mk} \qquad (2)$$

M - average long-term weighted average irrigation rate by crop rotation, mm;

B - the weighted average by crop rotation value of the crop removal of nitrogen, phosphorus or potassium, kg/ha;

k is a coefficient that takes into account the assimilation of nutrients by the crop: on soils with a low supply - for nitrogen 0.5, phosphorus and potassium 0.8; with an average supply - for nitrogen 0.6, phosphorus and potassium 0.85; with high security - for nitrogen 0.8, phosphorus and potassium 0.9.

The removal of nutrients from the soil by the planned harvest, the timing of irrigation and fertilization are taken according to the data of agricultural and agrochemical institutions.

Thus, the permissible values of the content of chemical elements in wastewater during their regular use for irrigation and the conditions for their use, depending on the type of soil of the irrigated area as a whole, should be presented as follows, as presented in Table 5 [8].

Table 5. Proposed permissible levels of pollutants in wastewater used for irrigation and conditions for their use.

Indicators	Acceptable content	Recommendations for the use of waste water
pH	***6,0-8,5***	***On all types of soil***
(Na + K)/[(Ca + Mg)]/2, mg-eqv/l	*8*	*On all types of soil*
	10	*On medium to light soils*
	12	*On light-textured soils*
Na + K + Ca + Mg, mg-eqv/l	*20*	*On all types of soil*
	<45	*On medium and light soils in terms of texture, when carrying out one leaching irrigation per year*
	≤45	*On medium to light soils. All irrigations or every second should be flushed*
	>45	*On light, well-drained soils. All waterings must be flushed*
Mg:Ca	*< 1,0*	*On all types of soil*
Total nitrogen N, mg/l	*50-100*	*On all types of soil. Irrigation is carried out taking into account the water consumption of crops*
Phosphorus P, mg/l	*10-30*	
Potassium K, mg/l	*15-20*	*The lack of a macronutrient is replenished with mineral fertilizers based on the needs of agricultural crops*

Table 6. Microbiological and parasitological indicators of the quality of wastewater used for irrigation.

Indicators quality of Agricultural run-off waters	Permissible content in 1 liter
LPK (lactose-positive E. coli) number	< 10000
Pathogenic microorganisms (according to epidemiological indicators)	Absence
Viable intestinal protozoan cysts (dysentery amoeba, lamblia)	1
Viable helminth eggs (roundworm, whipworm, pinworms, toxacar, fasciola, tennyid, dwarf tapeworm)	1

The sanitary-hygienic and veterinary-sanitary assessment of the quality of CDW's used for irrigation is carried out according to microbiological and parasitological indicators[11].

4 Conclusions

The effectiveness of utilizing CDW for irrigation is dependent on the efficient management and continuous monitoring of changes in the quality of both irrigation water and soil conditions in the irrigated area, crop yield, as well as groundwater and drainage. While the suggested monitoring framework can be tailored to suit specific circumstances, it remains an essential aspect of successful CDW irrigation, which cannot be overlooked.

In order to successfully use CDW's for irrigation, it is essential to comply with both agromeliorative and sanitary-ecological criteria that ensure the suitability of CDW's for irrigation. In addition, it is important to minimize any potential negative impact on the ameliorative conditions and fertility of the irrigated soil, and to prevent the spread of infectious diseases. It is also necessary to ensure that the use of CDW's generates additional income while reducing the environmental impact of wastewater, particularly on aquatic environments. Considering all these factors is key to the successful use of CDW's for irrigation.

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