

PAPER • OPEN ACCESS

Using collector-drainage water in saline and arid irrigation areas for adaptation to climate change

To cite this article: M Kh Khamidov *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **422** 012121

View the [article online](#) for updates and enhancements.

You may also like

- [Physiological response and quality of red tilapia *Oreochromis* sp. in the culture system using lemna \(*Lemna perussila*\) as phytoremediator](#)
K Nirmala, L Widia, Y P Hastuti et al.
- [Degradation of some heavy metals in wastewater using aqua plants](#)
Hussein Janna
- [Lemna minor cultivation in the climatic conditions of Saint Petersburg](#)
T Kuznetsova, N Politaeva, A R Ivanova et al.



245th ECS Meeting • May 26-30, 2024 • San Francisco, CA

[Learn more & submit!](#)

Present your work at the leading electrochemistry & solid-state science conference.

Network with academic, government, and industry influencers!

Submit abstracts by December 1, 2023



Using collector-drainage water in saline and arid irrigation areas for adaptation to climate change

M Kh Khamidov¹, D Balla², A M Hamidov^{2,3} and U A Juraev⁴

¹ Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 39, Kary-Niyaziy ave., Tashkent, 100000, Uzbekistan

² Leibniz Centre for Agricultural Landscape Research (ZALF), 84, Eberswalder Straße, Müncheberg, 15374, Germany

³ Humboldt-Universität zu Berlin, 6, Unter den Linden, Berlin, 10099, Germany

⁴ Tashkent Institute of Irrigation and Agricultural Mechanization Engineers Bukhara Branch, 32, Gazli shokh ave., Bukhara, 105009, Uzbekistan

E-mail: buhtimi@mail.ru

Abstract. The paper presents data of scientific research on the conditions of the Bukhara oasis of Uzbekistan reducing the salinity of collector-drainage water through water plants *Lemna minor*, *Azolla caroliniana*, *Eichhornia crassipes* and scientific and practical recommendations for the irrigation of cotton biologically purified collector-drainage waters. A decrease in the salinity of collector-drainage water with a salinity of 3-5 g/l was achieved with the help of aquatic plants *Lemna minor* and *Azolla caroliniana*, using them as an additional source of water for irrigation of cotton variety Bukhara-102, a high harvest of raw cotton, as well as saved river water and prevented environmental pollution.

1. Introduction

Over the past 60 years in the world, drinking water consumption has increased over 8 times. By the middle of the century, many states will be forced to import water. Water is a very limited resource, so now its sources are becoming one of the causes of conflict situations and the basis of geopolitics on the planet [1].

World agriculture annually consumes more than 2.8 thousand km³ of fresh water - up to 70 % of its global consumption, or 7 times more than world industry. Almost all of this volume goes to irrigation.

Worldwide water consumption growth at such a rate leads to a global water shortage. The development of new water resources requires an increasing investment in the maintenance of water management systems. Each cubic meter of water will cost more and more expensive, which will complicate the solution of the problem of access to water for developing countries. In the case of maintaining a modern model of water use and an increase in per capita water consumption, its availability will steadily decline.

Today, the Republic of Uzbekistan uses 54–55 billion cbm of water, of which 92 % is used in irrigated agriculture. The average annual use of water resources to irrigate the land in the Bukhara region is 4.2–4.6 billion m³, of which almost 50 % (1.9–2.3 billion cbm) is carried out by collector-drainage systems outside the region. Mineralization of collector-drainage water is from 2 g/l to 15 g/l. During a period of water shortage, their direct reuse in irrigated agriculture can increase soil



salinization, which will negatively affect the growth, development of plants and contribute to a decrease in the yield by 30–80 % [2,3].

In the practice of irrigated agriculture in the world (USA, China, India, Israel, etc.), due to the use of scientifically-based on irrigation regimes in conditions of water shortages, water-saving irrigation methods, the use of collector-drainage and waste water, savings have been achieved in river water and increase agricultural productivity crops by 10-15 %.

The use of collector-drainage water to irrigate agricultural crops, as well as the effect of their mineralization on the reclamation state of irrigated lands, was carried out by scientists: K.M. Mirzazhonov, F.M. Rakhimbaev, G.I. Ibragimov, G. Bezborodov, M.Kh. Khamidov, S.Azimov, S.K.Urinboev, T.Razhabov, M.Makhmudov, A.Abdukarimov, O.Turdialiev, L.Stepanova, S.Isaev, D.Balla, S.Maasen, and etc.

According to some researches, in arid and semi-arid climatic zones, salinity prior to nutrient is considered as the primary factor restricting crop production [4,5]. Saline drainage and fertiliser loss are co-products of agriculture, which could be retained in vegetated drainage ditches. For water-saving purposes, irrigation with light-salinity drainage recycling is suggested as an agricultural practice [5].

Couple of researchers studied duckweed plants and calcium-mediated responses of greater duckweed under diethyl phthalate stress were investigated [6]. Some other researchers studied culture of duckweed (*Lemna disperma*), their use and effects [7].

Research of some scientists showed that salt stress inhibited N and P removal by *L. minor*. Higher salt stress exerted more inhibitive effects on N and P removal. High-salt stress severely injured duckweed and reduced removal efficiencies of N and P even to negative levels. Longer cultivation time helped duckweed remove more N and P under low-salt stress and, conversely, induced more reduction in removal efficiencies under high-salt stress. Their results suggest that *L. minor* should be used to remove N and P from water with salinities below 75 mM NaCl or equivalent salt stress [8].

Some other scientists' study elaborated that plant and algae are able to cooperate with microorganisms to enhance organic pollutants and nutrients removal from POME, which can contribute in improving our environment in the future. Algae species were suggested to be used as bio-fertilizer as an alternative to mainstream synthetic fertilizers. This is due to the increased cost of chemical fertilizer that cause soil and water contamination. In comparison, algae are a cheap source of nutrients that do not cause pollution. Further investigations need to be carried out in the future on an actual scale such as agro-waste POME pond for industrial purposes [9].

Other scientists mentioned that better management of drainage is a key opportunity for this justifies the need for more research to optimize the management options for controlled drainage to avoid problems with soil salinity [10].

The aim of the research is to study the conditions of the Bukhara oasis to reduce the salinity of collector-drainage water with the help of watering plants *Lemna minor*, *Pistia stratiotes*, *Azolla caroliniana* and develop scientific and practical recommendations for cotton irrigation with improved collector-drainage waters.

2. Materials and methods

Field, laboratory studies and phenological observations were carried out according to the method "Methods for conducting field experiments" (UzICC 2007) and methods adopted by Leibniz Centre for Agricultural Landscape Research (ZALF), the international standard DIN, the amount of salts was determined in the laboratory using METRONOM-858 instruments, UGT-Ump-1, Multi 3620 IDS SET G, Multi 3410 SET 7 and SPEKORD-200.

The reliability and accuracy of the data obtained was checked on the basis of the generally accepted methodology "Mathematical processing of field experiment results" by B.A. Dospekhov, as well as on the basis of the SPSS (Statistical Package for Social Science) computer program.

In a special laboratory of the Bukhara branch of TIAME, the properties of reducing the mineralization of collector-drainage water of aquatic plants were determined: *Lemna minor*, *Pistia stratiotes* and *Azolla caroliniana* in 4 variants and 3 replicates: in the 1st variant, mineralization of

collector-drainage water was 1.0-3.0 g/l; in the 2 embodiment, 3.0-5.0 g/l; in version 3 above 5.0 g/l and in the control version 4 without sowing aquatic plants.

During laboratory and field experiments, the following scientific studies were carried out: the amount of salts of drainage water was determined by samples obtained every 12 hours by an electronic conductivity meter, as well as in laboratory conditions; the amount of nutrients, nitrate, phosphate, potassium was determined from samples obtained every 12 hours under laboratory conditions (the total amount of nitrogen and potassium was determined by the methods of A.P. Gritsenko and I.M. Maltseva, the amount of nitrate nitrogen using an ionomer Gronwald-Lyazh, active phosphorus according to B.P. Machigin, exchange potassium using a flame photocolormeter by the method of P.V. Protasov); phenological observations (quantity, mass and surface coverage of water) of the growth and development of water plants *Lemna minor*, *Pistia stratiotes* and *Azolla caroliniana* were carried out by determining the surface coverage of the water and its mass every 12 hours for all variants and repetitions; the effect of air temperature on the growth and development of water plants *Lemna minor*, *Pistia stratiotes* and *Azolla caroliniana* was determined by their growth and development factors every 12 hours for all variants and repetitions.

Under field conditions, small pools were held along open collectors and the following observations were made: after sowing *Lemna minor* plants, every 12 hours, as well as before irrigation water was supplied, the dry residue, the number of cations and anions of drainage water were determined; the amount of nutrients in the drainage water sown by the *Lemna minor* plant was determined every 12 hours, as well as before water was supplied for irrigation; the temperature of the drainage water was determined every 12 hours, as well as before the supply of water for irrigation. Phenological observations of the water plant *Lemna minor* (biomass, water surface area of the pool) were carried out every 12 hours before sowing until the end of the experiment.

3. Results of laboratory and field experiments

For scientific research in laboratory conditions, aquatic plants *Lemna minor*, *Pistia stratiotes* and *Azolla caroliniana* were planted in drainage water. The mineralization of collector waters according to the options is as follows: in the first embodiment, the dry residue was 2.74 g/l, chlorine ion –0.216 g/l, sulfate ion –0.785 g/l, ion HCO₃ –0.164 g/l; in the 2nd embodiment, the dry residue is 4.1 g/l, the chlorine ion is 0.386 g/l, the sulfate ion is 1.328 g/l, the ion is HCO₃-0.414 g/l; in version 3, the dry residue is 5.5 g/l, the chlorine ion is 0.678 g/l, the sulfate ion is 2.499 g/l, the ion is HCO₃-1.181 g/l.

In laboratory conditions, it was found that good absorption of chlorine in drainage waters with a salinity of 1-3 g/l was observed with the use of the water plant *Lemna minor*. If before sowing an aquatic plant the amount of chlorine in drainage water was 0.216 g/l, then at the end of the experiments this indicator was 0.195 g/l. This indicator was equal to 0.204 g/l in option 2 with an aquatic plant of *Pistia stratiotes* and 0.208 g/l in option 3 with an aquatic plant of *Azolla caroliniana*. The control variant — in the research variant without seeding of aquatic plants, the amount of chlorine in the drainage water was 0.235 g/l.

If, before sowing, the dry residue of drainage water was 2.74 g/l, then by the end of the experiments, in option 1, when sowing *Lemna minor*, this indicator dropped to 2.40 g/l. If in the second embodiment, when sowing *Pistia stratiotes*, the dry residue decreased to 2.55 g/l, then in the 3rd variant, when sowing *Azolla caroliniana*, this indicator was 2.60 g/l. In the control variant, the dry residue increased by 106 % relative to the initial result and amounted to 2.90 g/l.

The analysis of the results of the experiment to determine the effect of water plants on the amount of salts in collector-drainage waters with a salinity of 3-5 g/l showed that the amount of chlorine ion at the beginning of the experiments was 0.386 g/l (Fig. 1), then by the end of the experiments, in option 1, when sowing *Lemna minor*, this indicator decreased to 0.278 g/l, which shows a decrease of 28 %. If in the second embodiment, when sowing *Pistia stratiotes*, the amount of chlorine decreased to 0.312 g/l, then in the third variant, when sowing *Azolla caroliniana*, this indicator was 0.345 g/l. In the control variant, the amount of chlorine increased by 8 % relative to the initial result and amounted to 0.416 g/l.

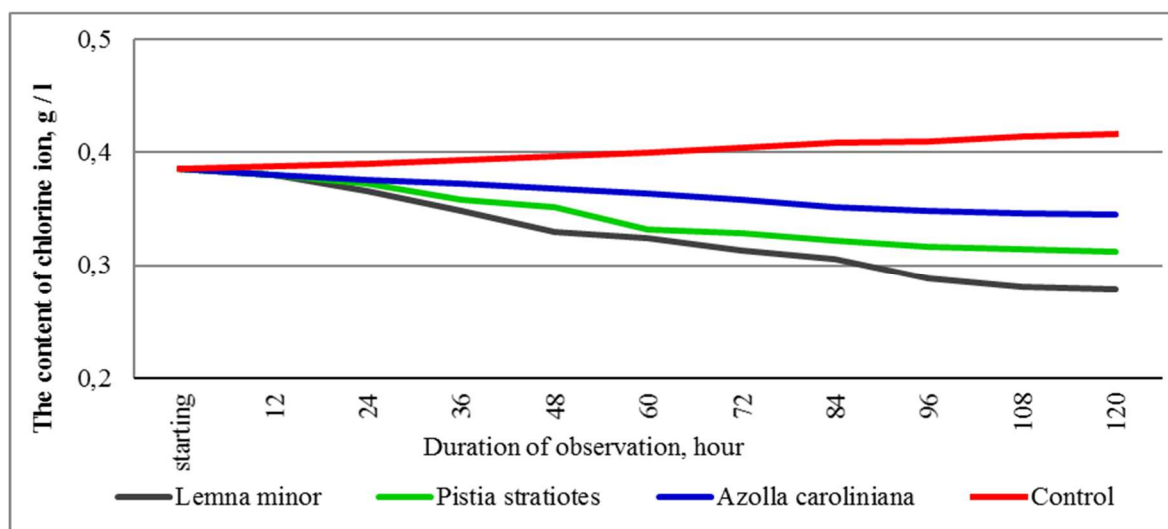


Figure 1. Water plants' effects on the amount of chlorine in drainage water.

As a result of the experiments carried out to reduce the salinity of drainage water, the *Lemna minor* aquatic plant showed the highest efficiency: in water with a salinity of 3-5 g/l. the decrease in the amount of salts in the drainage water was 28 % for chlorine ion and 22 % for dry residue.

The same results were obtained in experiments in the ZALF laboratory (Germany). The experiments in the ZALF laboratory were carried out to study the dynamics and the degree of decreasing in the salinity of the collector-drainage water by the *Lemna minor* aquatic plant in 3 variants and 3 repetitions: in the 1st variant (control), the salinity of the collector-drainage water was 0.3 g/l; in the 2 embodiment, 1.4 g/l; in version 3, 2.8 g/l.

The studies showed that in the control version at the beginning of the experiment, the electrical conductivity of the drainage water was 990 $\mu\text{S}/\text{cm}$, then after 17 hours, this indicator was 917 $\mu\text{S}/\text{cm}$ and this is 73 $\mu\text{S}/\text{cm}$ less than the initial indicator. By the middle of the experiment, after three days, this indicator was 860 $\mu\text{S}/\text{cm}$, and at the end of the experiment, the electrical conductivity of the drainage water was 827 $\mu\text{S}/\text{cm}$, which is 163 $\mu\text{S}/\text{cm}$ less than the initial indicator. During the experiments, 4.8 mm of precipitation fell, and the evaporation of drainage water was 10 mm.

In the second version of the observations, the amount of salts in the drainage waters was 1.4 g/l, then after 17 hours of experiment this indicator was 1.3 g/l. On the 3rd day of the study, the amount of drainage water salt was also 1.3 g/l, this indicator decreased to 1.2 g/l and remained until the end of the experiments. The electrical conductivity of the drainage water has decreased. For example, if in option 2 at the beginning of the experiment the electrical conductivity was 2990 $\mu\text{S}/\text{cm}$, then after 17 hours this indicator was 2900 $\mu\text{S}/\text{cm}$, which is 90 $\mu\text{S}/\text{cm}$ less than the initial indicator. If by the middle of the experiment, after 72 hours, this indicator was 2820 $\mu\text{S}/\text{cm}$. At the end of experiment 2 of the option, the electrical conductivity of the drainage water was 2720 $\mu\text{S}/\text{cm}$. In the second variant, a decrease in the conductivity of the drainage water by 270 $\mu\text{S}/\text{cm}$ from sowing to the end of the experiment was determined.

In the 3rd research variant, 2 g/l sodium chlorine was added to drainage water before sowing *Lemna minor*. If before sowing the amount of salts in the drainage water was 2.8 g/l, then after 17 hours of experiment this indicator was 2.7 g/l, i.e. the decrease was 0.1 g/l. The research results showed that after 72 hours the amount of salts was 2.6 g/l, after 84 hours their amount decreased to 2.5 g/l. By the end of the study, this value was 2.3 g/l, i.e., a decrease of 0.5 g/l in comparison with the beginning of the experiments. In the 3rd research variant, as well as in other variants, one can see a decrease in electrical conductivity by the end of the experiments. At the end of the experiments, after 144 hours in the 3rd embodiment, the electrical conductivity of the drainage water was 4750 $\mu\text{S}/\text{cm}$.

As a result of the experiments conducted to reduce the salinity of drainage water, high efficiency was achieved by growing *Lemna minor* in drainage water with a salinity of 2.8 g/l. With this mineralization, *Lemna minor* provides an 18 % reduction in the amount of salt in drainage water. And in drainage waters with a salinity of 1.4 g/l, the reduction in salt will be 15 %.

Field studies were carried out in 2018-2019 in the Kagan district of the Bukhara region, in small basins located along the Ubachul reservoir. During the field studies, the mineralization of the water of the Ubachula collector was 3.4 g/l. Field experiments were carried out according to the scheme (table 1).

Table 1. Experimental scheme of field experiment on cotton irrigation through biologically treated collector-drainage waters

Variant	Pre-irrigation soil moisture, %	Norm of mineral fertilizers, kg/ha	Irrigated water
1 (control)			irrigation with drainage water (without water plants)
2			irrigation with biologically cleaned with <i>Lemna minor</i> drainage water
3	70-75-65 %	N250; P175; K100.	irrigation with drainage water biologically cleaned with <i>Azolla caroliniana</i>
4			irrigation with drainage water biologically cleaned with <i>Eichhornia crassipes</i>

Pre-irrigation soil moisture of 70-75-65% HB and the norm of mineral fertilizers N-250; P-175; K-100 adopted on the basis of recommendations UzICC for Bukhara region. The dimensions of each pond: length 14 m., Width 6 m., Depth 4 m (Fig. 3).

At the beginning of the study, water plants *Lemna minor*, *Azolla caroliniana*, and *Eichhornia crassipes* were seeded over an area of 20 m². The growth and development of aquatic plants was monitored every 12 hours.

When sowing *Lemna minor*, the surface area of the water covered by the plant was 20 m², after 24 hours it was 26 m², after 72 hours - 45 m², and at the end of the observations, before using drainage water to irrigate cotton (after 204 hours) it was 84 m², i.e., the water surface in the pond was completely covered.

When sowing *Azolla caroliniana*, the water surface area covered by the plant was 20 m², after 12 hours - 25 m², after 72 hours - 50 m², after 120 hours - 75 m² and at the end of observations, after 180 hours, before using drainage water for irrigation of cotton it amounted to 84 m².

When sowing *Eichhornia crassipes*, the surface area of the water covered by the plant at the beginning was 20 m², after 24 hours - 22 m² and at the end of the observations, after 204 hours, before using drainage water for irrigation of cotton, it was 30 m².

Comparing the data on the growth, development and biomass formation of *Lemna minor*, *Azolla caroliniana* and *Eichhornia crassipes*, it can be concluded that in collector-drainage waters with a salinity of 3-4 g/l, the best development was in *Azolla caroliniana*, then in *Lemna minor* and *Eichhornia crassipes*.

Decreased mineralization of drainage water by aquatic plants.

The results of researches relevant to the influence of water plants *Lemna minor*, *Azolla caroliniana* and *Eichhornia crassipes* on the salinity of collector-drainage waters are given in table 2.

Table 2. Influence of water plants on the dynamics of mineralization of collector-drainage water

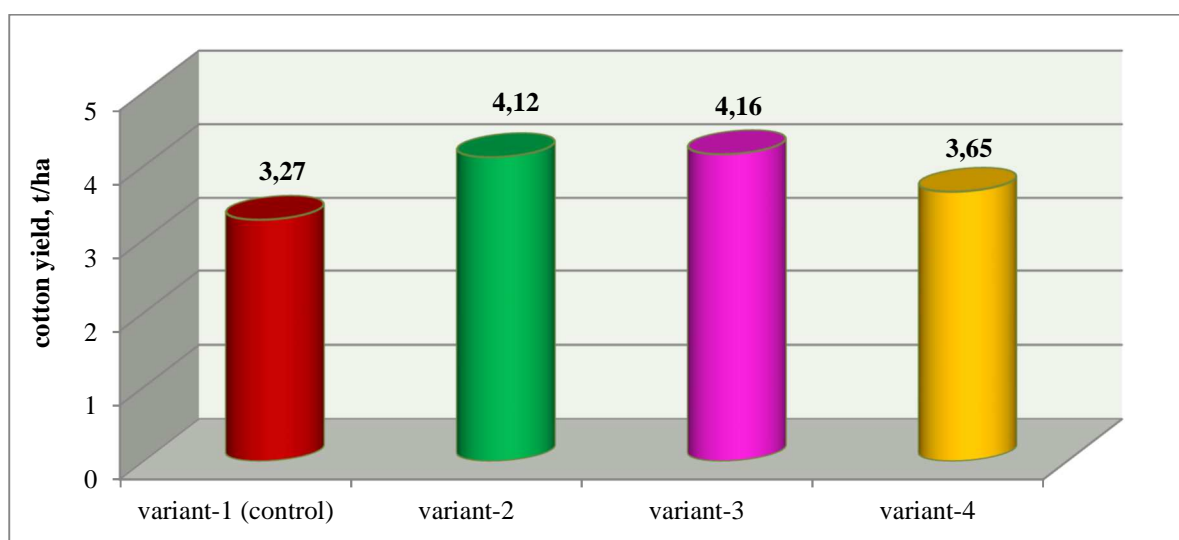
ions	At the beginning of research		At the end of research					
			Lemna minor		Azolla caroliniana		Eichhornia crassipes	
	g/l	%	g/l	%	g/l	%	g/l	%
Cl	0.363	100	0.274	75	0.285	78	0.298	82
SO ₄	1.308	100	1.088	83	1.14	87	1.158	89
HCO ₃	0.456	100	0.252	55	0.270	59	0.272	60
Na	0.3285	100	0.281	85	0.291	89	0.295	90
Mg	0.397	100	0.282	71	0.299	75	0.305	77
Ca	0.216	100	0.162	75	0.188	87	0.172	80
dry residue	3.35	100	2.45	73	2.6	77	2.65	78

To determine the effect of aquatic plants on the salinity of drainage water, good absorption of chlorine ion by the water plant *Lemna minor* was established. If before sowing the amount of chlorine in drainage water was 0.363 g/l, then at the end of the experiments this indicator was 0.274 g/l. The chlorine ion content in the variant with the aquatic plant *Azolla caroliniana* was 0.285 g/l and in the variant with the aquatic plant *Eichhornia crassipes* 0.298 g/l

If before sowing, the dry residue in the drainage water was 3.35 g/l, then by the end of the experiments, in the variant with *Lemna minor*, this indicator decreased to 2.45 g/l. with *Azolla caroliniana* and *Eichhornia crassipes* up to 2.60; 2.65 g/l.

The effect of irrigation with biologically purified drainage water on cotton productivity.

In option 1, where the irrigation was carried out with drainage water, the cotton yield of the Bukhara-102 variety was 3.27 t/ha, which is 0.87 t/ha less than in option 3, where the irrigation was carried out with biologically purified drainage water using *Azolla caroliniana* and 0.83 t/ha less than in option 2, where irrigation was carried out with biologically purified drainage water using *Lemna minor*. In option 4, where irrigation was carried out with biologically purified drainage water using *Eichhornia crassipes*, the yield was 3.65 t/ha (Figure 2).

**Figure 2.** Effect of irrigation with various quality water on the productivity of cotton, t/ha.

In option 3, where the pre-irrigation soil moisture was maintained at the level of 70-75-65% HB, against the background of the N-250, P-175, K-100 kg/ha mineral fertilizers, the irrigation was carried

out with drainage water, biologically reduced mineralization and enriched with nitrate nitrogen with the help of *Azolla caroliniana*, the most favorable soil, water, air, salt and nutrient regimes were created, which ensured a high yield of raw cotton.

4. Conclusion

The irrigated lands of Bukhara region comprise 275.1 thousand ha, of which 170.1 thousand ha (61.8 %) of lands with mineralization of groundwater 1-3 g/l, 96.3 thousand ha (35 %) of land with salinity of groundwater 3-5 g/l, 8.5 thousand ha (3.1%) of land with salinity of groundwater 5-10 g/l and 1.2 thousand ha (0.45 %) of land with salinity of groundwater more than 10 g/l.

For agricultural needs of Bukhara region, 4.1-4.3 billion cbm of water resources are used annually. Every year, 2.1 billion cbm of water is discharged from the irrigated territories of the region to use collector-drainage systems. During the years of acute shortage of water resources, 61 % of them can be reused, and 5.23 % of the collected collector-drainage water can be used in irrigated agriculture mixing them with river water, which reduces the negative consequences of the water shortage.

When the water plant *Lemna minor* was grown under laboratory conditions in drainage water with a salinity of 3-5 g/l, the best results were achieved: the amount of chlorine was reduced to 25 %, and the amount of solids to 27 %. When growing aquatic plants *Azolla caroliniana* and *Eichhornia crassipes*, the decrease in the amount of chlorine in drainage waters was 22 % and 18 %, and the solid residue was up to 23 % and 22 %.

In option 3, where the pre-irrigation soil moisture was maintained at the level of 70-75-65 % HB, against the background of N-250, P-175, K-100 kg/ha mineral fertilizers, irrigation was carried out with biologically reduced mineralization and enriched with nitrate nitrogen with the help of *Azolla caroliniana*, the most favorable soil water, air, salt and nutrient regimes were created, which ensured a high yield of raw cotton: up to 4.16 t/ha.

5. Recommendations

In the years of severe water shortages in order to reduce its negative consequences, as well as on lands where river water delivery is difficult, farmers can use drainage water with a salinity of 3-5 g/l to irrigate cotton seed of the Bukhara-102 variety by reducing them mineralization with the help of water plants *Lemna minor* and *Azolla* (*Azolla caroliniana*). This creates opportunities for biogas production using aquatic plants as bioorganic waste, as well as biofertilizer production, a product of processing water plants used to reduce the mineralization of drainage water.

References

- [1] Khamidov M Kh, Jurayev U A, Kadirov Z Z and Saksonov U 2018 Reduction of mineralization of collector-drainage water by the biological method and use of them in the irrigated agriculture. *European Science Review* **11-12** 55
- [2] Khamidov M Kh and Juraev U A 2016 Decrease in salinity of collector-drainage waters. *Agricultural science* **6** 2-4
- [3] Mirzajonov K M 2009 *From the history of meliorative works of the Uzbek Research Institute of Cotton*. (Tashkent: UzICC, PSUEAITI, IKARDA) 11-15
- [4] Pitman M G, Läuchli A and Lüttge U 2002 *Salinity: Environment-Plants-Molecules*. (Dordrecht: Kluwer Academic Publishers)
- [5] Pan Wua, Boqiang Qina, Zhishan Zhanc, Yigang Huc and Yongle Chenc 2015 Effects of drainage water on plant diversity and distribution of agricultural drainage ditch beds in an arid irrigated area of Northwestern China. *Chemistry and Ecology* **8** 679-691
- [6] Cheng L J et al 2018 Calcium-mediated responses and glutamine synthetase expression in greater duckweed (*Spirodela polyrhiza* L.) under diethyl phthalate-induced stress *Aquatic Toxicology* **144-145** 124-132

- [7] Abdul J M et al 2012 Use of duckweed (*Lemna disperma*) to assess the phytotoxicity of the products of Fenton oxidation of metsulfuron methyl. *Ecotoxicology and Environmental Safety* **83** 89-95
- [8] Chunguang L, Zheng D and Hongwen S 2017 Potential of duckweed (*Lemna minor*) for removal of nitrogen and phosphorus from water under salt stress *Journal of Environmental Management* **187** 497-503
- [9] Hesam K, Shreeshivadasan Ch, Mohd Fadhil M D, Reza Sh Y, Shahabaldin R, Tayebbeh Kh, Ashok K and Mohammadamin Azimif 2017 Evaluation of *Lemna minor* and *Chlamydomonas* to treat palm oil mill effluent and fertilizer production. *Journal of Water Process Engineering* **17** 229-236
- [10] Hamidreza J J, Abdolmajid L, Alireza H and Ritzema H 2018 Managing controlled drainage in irrigated farmers' fields: A case study in the Moghan plain *Agricultural Water Management* **208** 393-405