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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН
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REGULATION OF WATER-SALT REGIME OF IRRIGATED LANDS IN THE LOWER REACHES OF THE SYRDARYA RIVER

Abstract. Mineralization of water in the Syrdarya River, the current state of the soil-reclamation structure of irrigated lands located in the lower reaches of the river is at a very poor level. The salinity of the soil, as well as the salinity of the collector-drainage water, is extremely high. The average annual mineralization of river water at the Tomenaryk gauging station reaches 2.0-2.5 g/l, and at the Kazaly gauging station it is -3.0-3.5 g/l. And the process of soil salinization occurred almost throughout the region. According to recent data, the area of saline irrigated land in Kyzylorda region is about 225.9 thousand ha, of which slightly saline - 87.6 thousand ha, medium saline - 73.3 thousand ha, strongly and very strongly saline - 65.1 thousand ha. Kyzylorda region is mainly cultivating rice (as well as alfalfa, corn for silage, sunflowers, etc.). Taking this into account, secondary salinization was observed on rice fields due to poor work of collector-drainage systems.

To optimize this issue, the article presents the current state of irrigated lands in the lower reaches of the Syrdarya River in Kyzylorda region, as well as the results of work on the regulation of water-salt regime. For this purpose, research work was carried out on 71.15 hectares of agricultural land Bidaikol (former Giant), which belongs to the Zhanakorgan-Shieli irrigation massif. According to the research results, it was optimal to provide fields with water through a specially prepared biofield planted with dense reed plants. It was proved that purified irrigation water from the biofield is effective for irrigation of fodder crops. In addition, the reeds themselves are widely used in the republic as a fodder crop. The young reeds collected in August (at this time the reeds will be soft and the leaves green) are finely chopped and stored using a special press technology. Because of the growing importance of winter fodder, the price of reed has increased significantly in the southern and southwestern regions of the country. For example, this year the price of 1 press of reed ranged from 650-850 tenge. In addition, there was a shortage of fodder in the western regions (Aktau, Mangistau) this spring.

Considering all these problems, that the work done in the article is very relevant and more effective.

Key words: salinity, experimental field, irrigated land, check plots, soil flushing, water-salt regime, collectors and drainages.

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СЫРДАРИЯ ӨЗЕНІНІҢ ТӨМЕНГІ АҒЫСЫНДАҒЫ СУАРМАЛЫ ЖЕРЛЕРДІҢ СУ-ТҰЗ РЕЖИМІН РЕТТЕУ

Аннотация. Сырдария өзені суының минерализациясы, өзеннің төменгі ағысында орналасқан суармалы алқаптардың топырақ-мелиоративтік құрылымының қазіргі жағдайы өте нашар деңгейде. Топырақтың тұздану мөлшері, одан қалды қашыртқы сулармен шыққан судың тұздану мөлшері өте жоғары. Төменарық гидробекеті тұсында өзен суының минерализациясының орташа жылдық көрсеткіші 2,0-2,5 г/л, Қазалы гидробекеті тұсында 3,0-3,5 г/л жетіп отыр. Ал топырақтардың тұздану процестері іс жүзінде облыстың барлық аумағы бойынша орын алған. Соңғы дерек бойынша Қызылорда облысының аумағында тұзданған суғармалы жерлердің ауданы 225,9 мың га шамасында, олардың ішінде әлсіз тұзданғаны – 87,6 мың га, орташа тұзданғаны –73,3 мың га және қатты және өте қатты тұзданған жерлер – 65,1 мың га. Қызылорда облысы негізінен күріш (сондай-ақ, жоңышқа, сүрлемдік жүгері, күнбағыс, бақша өсімдіктері т.б) өсіруге машықтанған. Осыны ескеріп, күріш егісі қалыптасқан жерлерде қашыртқы – дренаж жүйелерінің нашар жұмыс істеуінен екінші реттік тұздану жүретіндігі байқалды.

Осы аталған мәселені оңтайландыру бойынша, мақалада Сырдария өзенінің төменгі ағысындағы, Қызылорда облысы аумағындағы суармалы алқаптардың қазіргі жағдайы, олардың су-тұз режимін реттеу жұмыстарының нәтижесі берілген. Осы мақсатта Жаңақорған-Шиелі суармалы массивіне қарайтын Бидайкөл ауылшаруашылық жерінің 71,15 га жеріне тәжірибе жүргізілген болатын. Зерттеу жұмыстарының нәтижесін ескеріп егістікке берілетін суды арнайы дайындалған тығыз қамыс өсімдігі егілген биотанап арқылы беру оңтайлы екендігі белгілі болды. Биотанаптан тазаланып шыққан суармалы суды малазықтық дақылдарды суаруға пайдалану әлдеқайда тиімді. Сонымен қатар қамыс өсімдігінің өзі малазықтық дақыл ретінде республикада кең таралған. Тамыз айында орылатын жас қамысты (ол кезде қамыс үпелектемей, діңгегі жұмсақ, жапырағы жасыл күйде болады) арнайы технологияның көмегімен майдалап турап, пресспен сақтайды. Қыстық мал азығын дайындаудың маңыздылығының жыл сайын артуына байланысты қамыстың бағасы да республиканың оңтүстік және оңтүстік-батыс өңірлерінде едәуір қымбаттаған. Мысалы, биылғы жылы 1 пресс қамыстың бағасы 650-850 тг бағасында құбылып отырды. Бұған қоса биыл көктемде батыс өңірлердегі (Ақтау, Маңғыстау өңірлері) жеп-шөп тапшылығын айтуға болады. Аталған жағдайларды ескере отырып, мақалада атқарылған жұмыстың өзекті екендігіне көз жеткізуге болады.

Түйінді сөздер: тұздану, тәжірибе танабы, суармалы жерлер, шектер, жуыпшаю, су-тұз режимі, қашыртқы.

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РЕГУЛИРОВАНИЕ ВОДНО-СОЛЕВОГО РЕЖИМА ОРОШАЕМЫХ ЗЕМЕЛЬ В НИЗОВЬЯХ РЕКИ СЫРДАРЬИ

Аннотация. Минерализация воды реки Сырдарья, современное почвенно-мелиоративная состояние орошаемых земель, расположенных в низовьях реки Сырдарьи, очень плохие. Засоленность почвы и засоленность коллекторно-дренажных вод очень высоки. Среднегодовая минерализация речной воды на Томенарыкском гидропосте составляет 2,0-2,5 г/л, а на Казалинском гидропосте – 3,0-3,5 г/л. Причем процесс засоления почв происходил практически на всей территории области. По последним данным, площадь засоленных орошаемых земель в Кызылординской области составляет около 225,9 тыс.га, из них слабозасоленные – 87,6 тыс.га, среднезасоленные – 73,3 тыс.га, сильно и очень сильнозасоленные – 65,1 тыс.га. Кызылординская область в основном занимается выращиванием риса (а также люцерны, кукурузы на силос, подсолнечника и др.). Учитывая это, на рисовых полях наблюдалось вторичное засоление из-за плохой работы коллекторно-дренажных систем.

Для оптимизации данного вопроса в статье представлено современное состояние орошаемых земель в низовьях реки Сырдарьи в Кызылординской области, а также результаты работы по регулированию водно-солевого режима. С этой целью исследовательские работы были проведены на 71,15 га сельскохозяйственных землях Бидаиколь (бывший Гигант), относящихся к оросительному массиву Жанакорган-Шиели. По результатам исследований оптимальным было обеспечение полей водой через специально подготовленное биополе, засаженное густыми тростниковыми растениями. Доказано, что очищенная поливная вода из биополя эффективна для орошения кормовых культур. Кроме того, сам тростник широко используется в республике как кормовая культура. Собранные в августе

молодой камыш (в это время камыш мягкий, а листья зеленые) мелко измельчают и хранят с помощью пресса по специальной технологии. Из-за растущего значения озимых кормов цена на тростник значительно выросла в южных и юго-западных регионах страны. Например, в этом году цена 1 пресса тростника колебалась в пределах 650-850 тенге. Кроме того, этой весной наблюдалась нехватка кормов в западных регионах (Актау, Мангистау). Учитывая все эти проблемы, освещенная в статье работа очень актуальна и наиболее эффективна.

Ключевые слова: засоление, опытное поле, орошаемые земли, чеки, промывка, водно-солевой режим, коллекторы и дренажы.

Introduction. The total water resources of the Syrdarya River basin averaged over a multi-year period about 37 billion cubic m. The main volume of the flow is formed in the upper part of the massif, starting from the Fergana Valley (territory of Uzbekistan). In Kazakhstan, the flow of the Syrdarya River, which originates in the Fergana Valley, collects in the Shardara Reservoir. Currently, the average annual volume of water in the Shardara reservoir is about 5 billion m^3. During the vegetation period, this indicator decreases by about 4 billion m^3. To regulate the seasonal flow of the Syrdarya River and to protect the region from floods, below the reservoir in Turkestan region the Koksarai reservoir (also called counter-regulator) was built. The reservoir's volume calculated at 3 km^3 (Fig.1).

Figure 1 - Shardara reservoir and Koksarai counter-regulator

The Kyzylorda and Kazaly waterworks facilities were built in the lower reaches of the Syrdarya river, in order to regulate water supply irrigated lands in Kyzylorda region. Their estimated flow rates are about 200 m^3/s and 90 m^3/s. The growth of irrigated areas in Kyzylorda region, also for the maximum effective regulation of water were built another Aitek and Aklak waterworks facilities near the Aral Sea.

There are 6 irrigated massifs (Tugusken, Zhanakorgan-Shieli, Kyzylorda Right Bank and Left Bank, Kazaly Right Bank and Left Bank irrigated massifs) in the lower reaches of the Syrdarya in Kyzylorda region. Their general scheme is shown in Figure 2. The irrigated massifs are mainly used for growing cereals, rice, sunflowers, vegetables, garden plants, potatoes and fodder crops (silage corn, alfalfa, etc.) (Materials, 2019), (Material, 2019).

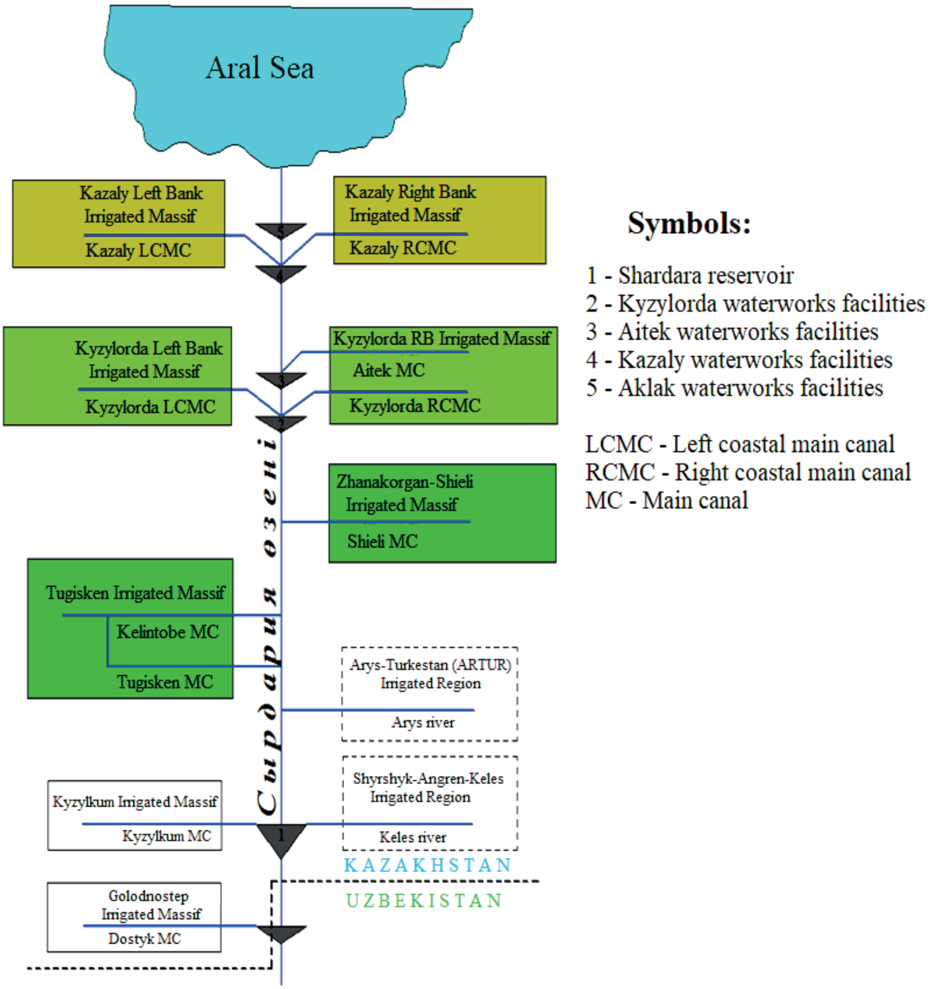

Figure 2 - Scheme of the location of irrigated massifs in the Kazakhstan part of the Syrdarya river basin

The total area of these irrigated massifs is about 220 thousand hectares, and used about 145 thousand hectares. The changes in the irrigated lands of the irrigated areas related to the Syrdarya River basin over the past five years are shown in Table 1 (Report, 2019).

Table 1- Changes of irrigated lands in the Syrdarya river basin in Kyzylorda region (thous. ha)

Years	Kyzylorda region	
	Available irrigated land	Used
2016	214,7	148,8
2017	217,9	153,1
2018	218,8	168,7
2019	218,8	154,5
2020	218,8	143,4

As the table shows, in recent years from 218.8 thousand hectares of irrigated land only 68% is used, 25% is in a satisfactory condition. This means that about 90-93% of irrigated land or about 200 thousand hectares of irrigated land can be planted. However, about 7-10% is highly salinized, i.e. completely unfavorable. Salt that has risen from the bottom of the Sea due to the shrinking of the Aral Sea causes salinization of irrigated land, as well as secondary salinization of irrigated land due to increased mineralization of the Syrdarya River water and collector-drainage waters. Currently, the state of irrigated massifs is in a very low technical condition. Many of them, built 35-40 years ago, need to be totally improved. At present, 45.1 thous.ha of irrigated land are in unsatisfactory condition. 21,8 thousand ha of them are salinized, 4,5 thousand ha are not properly prepared, in 18,8 thousand ha of irrigated lands irrigation and collector-drainage systems are non-operational. Accordingly, crop yields in the region are also low.

While investigating this issue, we conducted an experiment on 71.15 hectares of Bidaikol agricultural field relating to the Zhanakorgan-Shieli irrigated massif (Fig.3).

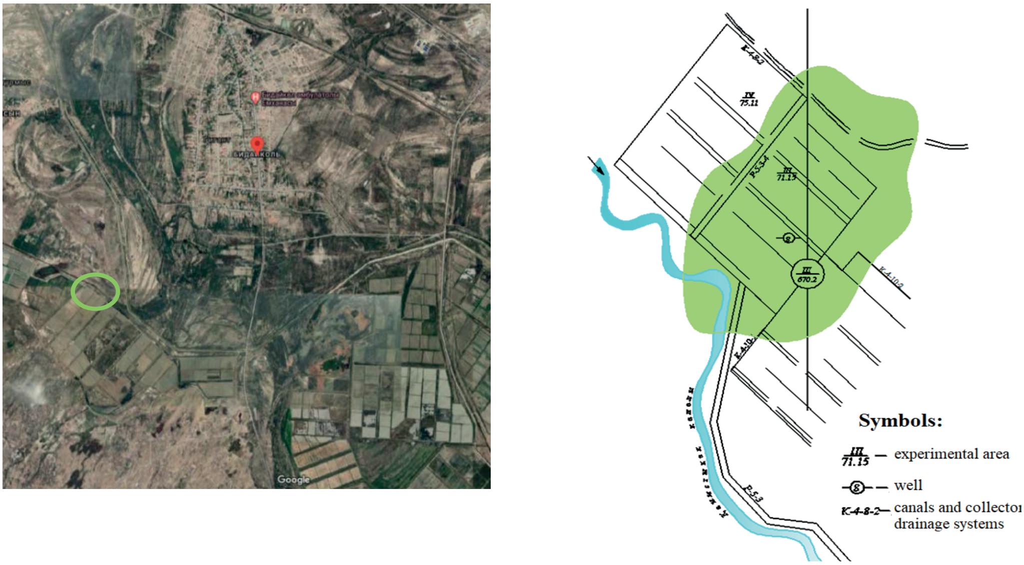

Figure 3 - Scheme of the experimental area location

Methodology. Chemical composition of water and soil were analyzed in special laboratories. Thus, total nitrogen (N), (pH), ammonium and nitrogen, sulfates (SO4) and chlorides (Cl) were determined by Rybnikov-Lurie methods, while calcium (Ca) and magnesium (Mg) were determined by complex-metric method, sodium (Na) and potassium (K) by photometer, chemical oxygen demand (COD) was determined by bichromatic approach (Goma, 2010), (Vojegov, 2020).

The chemical composition of soil was determined twice a year, i.e., in autumn and spring. Soil samples were taken at a depth of 60 cm, i.e., every 10 cm. Further, three samples were taken at a depth of 100 cm, i.e., every 20 cm, 3 returns each.

Soil moisture was determined by thermostatic and boring methods.

We determined the soil flushing rate of salts in the soil by equation of V.R. Volobuyev (Lopatovskaya, 2010):

$$M = \alpha \log\left(\frac{S_n}{S_0}\right) 10000 \quad (1)$$

here: M – flushing rate, м^3/ha;

S_n – the amount of salts in 1 meter layer of soil, %;

S_0 – salt limiting value in 1 meter layer of soil, %;

α - salt conductivity value of soil.

For the Kyzylorda region this indicator is presented as α=0.50 according to the data of Zh.Baimanov (Baimanov, 2017).

During the experiment, the flushing was carried out twice, with each flushing it was supplied with 2300 m^3 of water per hectare. The interval between the first flushing and the second flushing is about 5 days.

We determine the amount of salts infiltrated into the soil by multiplying the water saturation rate by the amount of salts transported with water. And we determine amount of salts that comes from the soil by multiplying volume of collector-drainage water by its salinity.

With the area of one check in the experimental area, equal to 0.5 hectares, the amount of water supplied to the check is 1150 m^3/hectare. Canal water discharge is 100 l/sec..

$$t = \frac{1150000}{100} = \frac{11500\ \text{sec}}{60\ \text{sec}} = \frac{192\ \text{min}}{60\ \text{min}} = 3{,}2 \quad \text{hour}$$

As a result, it takes 3 hours and 20 minutes to flush 1 check plot. Consequently, the whole 71 hectares can be flushed in 19 days. This is a one-time flushing. The repeated flushing is carried out every 5 days. Then the whole process of soil flushing will take 38 days.

Field research was conducted in 3 options:

- Option I. Water-salt regimes of soil under conditions of common irrigation (control);
- Option II. Water-salt regime after soil flushing works;
- Option III. Soil water-salt regime under water supply to crops through biofield.

The research work was carried out in 3 options, dividing 71.15 hectares into 3 fields of 24 hectares each. The fields were divided into check plots for soil flushing works. The area of each check plot is 2500 m^2 (100 x 25 m^2). There are 96 check plots in total. The area of the biofield is 5 hectares. It is divided into five parts. Each part has an area of 1 hectare. It is densely sown with reeds.

Each option had an area of 24 ha (field length 1200 m, width 200 m). Between each option was a protection belt with a width of 2 m.

In option 1 water supplied to the plot of the experimental field under operational conditions, i.e. according to the annual irrigation method. Salinity of water supplied to and discharged from the field was determined by the control work.

In the 2nd option the water supply to the experimental field was given after soil flushing works. Then according to the option the field was divided into 96 check plots. The length of each check plot was 100 m and the width 25 m. According to the research of A. Shomantaev it was proved that the mineralization of the river water in the lower reaches of the Syrdarya is closely related to the water discharge. With the increase of water discharge the salinity of the river decreases. It is especially noticeable in the period from March to May, when the water discharge of this river is considered the highest. During these periods, water salinity decreases to 900-1000 mg/l. Given this situation, it is best to carry out flushing work at this time of the year. The check plots for flushing is shown in Figure 4 (Shomantaev, 2001).

In the 3rd option, water was supplied to the field of experiment through a biofield planted with specially prepared dense reed plant. The reed plant has the ability to absorb and purify the amount of salts in water, according to studies of many scientists. Some scientists even call reed plants a biological filter (Anser Ali , 2012), (Shabbir, 2018), (Muthuraman, 2021). Water-salt regime of water flowing in and out of the biofield, as well as the volume and salinity of water released from the arable land were determined by the control works.

The biofield area was divided into five parts (1 hectare each). Each part works in turn (Figure 5).

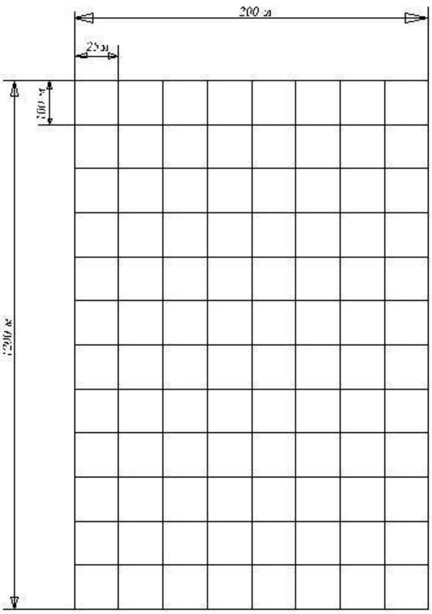

Figure 4 – Check plots scheme in option 2

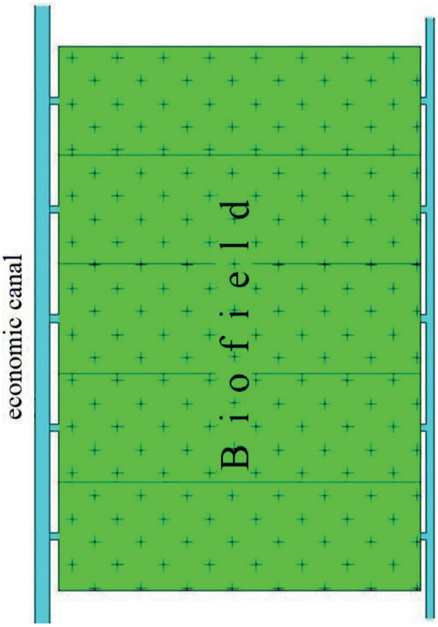

Figure 5 - Biofield scheme in option 3

Results. Initial salt content in the experimental plot of Bidaikol farm, where the study conducted, was 1.757% (by weight of dry soil). (Anuarbekov, 2015), (Anuarbekov, 2021). It was very difficult to get a good crop from this plot with such an indicator.

The index of useful salt for plants should be in the range of 0.3 to 0.5. Over 2 years, as a result of flushing work and water supply through a specially prepared biofield, salt content decreased from 1.757% to 0.422% (of dry soil weight). (Anuarbekov, 2013), (Anuarbekov, 2013). Accordingly, silage corn and alfalfa yields increased.

During the works, the total volume of water used to irrigate the crop, its salinity, as well as the volume of water released from the drainage and its salinity were determined. In three options, the planned and actually used amount of water, the volume of water flowing into the drainage, and the efficiency factor were determined (Table 2).

Table 2 - Data on the amount of water intake and water supply to crops during vegetation of crops in the experimental site, м³

Indicators	1st option	2nd option	3rd option
2019			
Water withdrawal (actual)	203 871	249 419	190 322
Water realesed to the field (actual)	126 400	154 640	118 000
Volume of water entering the drainage	32 864	35 309	30 680
EFFICIENCY	0,62	0,62	0,62
2020			
Water withdrawal (actual)	194 839	245 548	181 935
Water realesed to the field (actual)	120 800	152 240	112 800
Volume of water entering the drainage	31 408	33 583	29 328
EFFICIENCY	0,62	0,62	0,62

The relative indicator of water-salt regimes in three options was also determined, which is presented in Table 3.

Table 3 - Water-salt regimes of the field during the experiment

Indicators	1st option	2nd option	3rd option
Amount of water supplied to the field, m³	247 200	306 880	230 800
Salinity index of supplied water, g/l	2,03	2,03	1,64
Amount of salts that entered the soil, t	502,0	480,4	378,5
Amount of water released from the drainage, m³	64 272	68 892	60 008
Salinity index of released water, g/l	2,80	2,96	1,97
Amount of salts that flushed out with drainage, t	180,3	203,9	118,1
Total amount of salts remaining in the soil, t	321,7	276,5	260,4

That is, there is less salt left in the soil in option 2 than in option 1. This is because we did the flushing. And in the 3rd option there was almost 60 tons less than in the 1st option.

And also the water released from the fields is discharged outside through P-5-3-4 collector. Figure 6 shows the index of total salt content in the soil of the experimental zone and the dynamics of salt content during flushing works in the 2nd option.

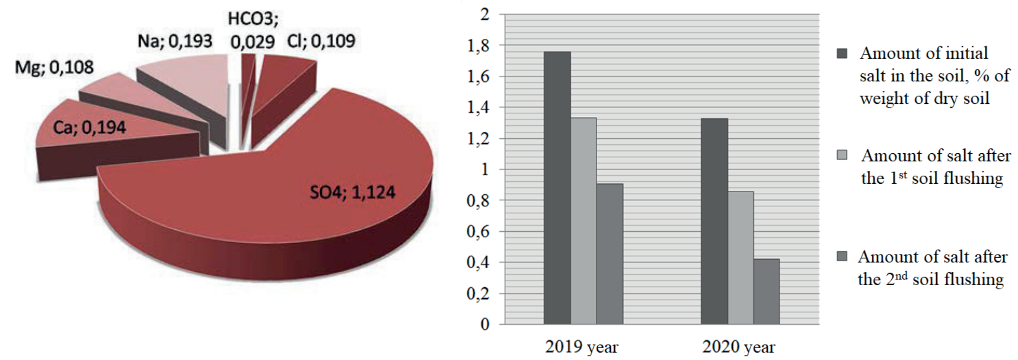

Figure 6 - Salt content in the soil in the experimental area and the dynamics of salt content during flushing works

It was observed that the work carried out (biofield, flushing) had a significant impact on the growth and yield of silage corn in the fields.

Research results show that the growth and development of the corn crop during the growing season was intensive when water was passed through the biofield in the 3rd option.

The area of corn leaves in one irrigation reached 7600 cm^2. Studies showed that growth and development of corn leaf area in 3rd option was 3000 cm^2 higher than in the 1st option, when water was supplied through the biofield.

The highest corn leaf growth (7,600 cm^2) was recorded in the second year (2020), which means that the plant reached 220 cm in height at harvest time.

The highest leaf yield was observed in the second half of July. At this moment begins the flowering phase of silage corn crops.

When harvesting silage corn, we sampled crops in each option (Table 4).

Table 4-Yields of silage corn, c/ha

Options	1st repetition	2nd repetition	3rd repetition	Average yield	Difference, compared with the 1st option
2019					
1- option	348	380	352	360	
2- option	385	390	395	390	+30
3- option	390	410	400	400	+40
2020					
1- option	363	366	375	368	
2- option	410	420	430	420	+52
3- option	442	460	451	451	+83
HCP_{05} – 27 c/ha, P,% - 3%					

In the option of flushing the salt in the soil corn yield was by 30-52 c/ha more than in option 1 (production conditions), in option 3 (water supply through the biofield) corn yield was by 40-83 c/ha more than in option 1. The highest productivity index was observed in option 3.

In the year when the experiment started, the alfalfa crop was a second-year crop. Alfalfa crops were watered 7 times and gave 5700 m^3/ha of water per hectare. The alfalfa crop was mowed three times a year. Option 1 yielded 116, 171, 131 (418 c/ha), option 2 yielded 126, 177, 163 (466 c/ha), and option 3 yielded 131, 183, 171 (485 c/ha) in that order. The alfalfa yield is presented in Table 5.

Table 5 - Indicators of alfalfa crop yield, c/ha

Options	1st repetition	2^{nd} repetition	3^{rd} repetition	Average yield	Difference, compared with the 1^{st} option
2019 year					
1- option	412	424	418	418	
2- option	462	468	468	466	+48
3- option	475	490	490	485	+67
2020 year					
1- option	410	414	412	412	
2- option	452	462	460	458	+46
3- option	470	482	476	476	+64

As you can see from the table, in 2019 we received 48 c/ha of additional production in option 2 compared to option 1, in option 3 we received 67 c/ha of additional production compared to option 1. In 2020 in this sequence we got 46 c/ha of additional production in option 2, 64 c/ha in option 3.

Discussion. Before soil flushing, it is better to carry out the following regular works:

systematic planning of sown areas;

planning of protecting belts at the height of 0.25 m;

carrying out maintenance works of canal systems, using Thompson trapezoidal spillway system to release water into the checks and its preparation;

determination of total amount of salts in 1 meter of soil layer in the first half of March 2019 before flushing works.

Based on the results of laboratory studies, the total salt content in 1 meter of the soil layer was 1.757% of the weight of dry soils. And in spring 2020 after the second flushing, the total salt content in 1 meter of the soil layer decreased by 0.422% of the weight of dry soils.

While the flushing of 71.15 hectares of Bidaikol farmland was supplied with 4,600 m^3/ha of water, as indicated above, the water tariff for Kyzylorda region in 2019 and 2020 was about 0.7 tg/m^3. That is, in 2019, 3,220 tg/ha were spent on flushing. Then during the year, 4,900 m^3/ha of water was supplied to alfalfa and silage maize crops, and 3,430 tg/ha was spent. In the study area in 2020, silage corn yielded an average 364 c/ha in the 1st option, 410 c/ha in the 2nd option, 426 c/ha in the 3rd option, alfalfa yields were 415 c/ha in the 1st option, 462 c/ha in the 2nd option, and 480 c/ha in the 3rd option.

Considering the results of these studies, we were convinced that the 3rd option is most optimal. Water supply through the biofield, planted with specially prepared dense reed plant, showed high results. The effectiveness of using irrigation water treated through the biofield for irrigation of fodder crops has been proven. In addition, the reed is widely spread in the republic as a fodder crop. Young reeds, which are harvested in August (at that time the reeds are not chopped, the stem is soft, the leaf is green), are finely chopped and stored by press using a special technology. Due to the annual increase in the importance of harvesting winter fodder, reed prices have also increased significantly in the southern and southwestern regions of the country. For example, this year the price for 1 press of reed was about 650-850 tg. In addition, in the spring of this year in the western regions (Aktau, Mangistau regions) there was a shortage of forage food. Taking into account all these circumstances, we can be convinced in the effectiveness of the 3rd option, i.e. the technology of water supply to the field through the biofield.

Conclusion. In the direction of the Syr Darya River towards the Aral Sea, collector-drainage water from the large rice massifs Kyzylkum, Tugusken and Kyzylorda on the left bank flows into the river bed. The combination of natural and anthropogenic factors leads to a significant increase in the salinity of the river water, the concentration of toxic salts in it, the formation of anthropogenic pollution in the form of toxic chemicals in the water.

According to recent data, 2.5-3.5 million tons of salt per year inflows from the irrigation massifs to the Syr Darya water through collector-drainage systems. Average annual salinity value in Tomenaryk was 1.5-1.7 g/l, in Kazaly - 1.7-1.8 g/l, and in particular periods maximum value reached 2.0 g/l in Tomenaryk, and in Kazaly - 3.0 g/l. At all values of mineralization the type of ionic composition was sulfate-sodium.

Therefore, under current conditions, in order to form a sustainable water-salt regime in irrigated areas, assess the reclamation state of irrigated lands and solve problems arising from the current environmental and social situation in the region, we still recommend the following comprehensive studies:

- annual comprehensive control of water salinity of the Syrdarya River;
- agrochemical photographing of saline lands;
- mapping of saline soil;
- study of water-physical composition of soil and norms of salt flushing in soil;
- revision and reconstruction of arable land structure;
- improvement of water distribution and water use management process;
- implementation of advanced technologies, technical and design solutions;
- collector-drainage water treatment and reuse in agriculture;
- treatment of wastewater and its reuse in agriculture.

In addition, to further improve the water-salt regime, it is recommended to supply water to the field through the biofield. Its area should be not less than 2% of irrigated area.

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