ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 11 , November 2022

A new technology for leaching saline soils

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ABSTRACT: This article is devoted to management of soil salinity and water-salt regime, conducting field experiments to assess soil reclamation conditions and increasing efficiency of salt washing. Today, 46.6% of the irrigated land of the Republic of Uzbekistan are saline, including 30.9% - slightly, 13.3% - medium and 2.5% - highly. Medium and highly saline areas together make up 15.8%.
The difference of the recommended method of salt washing from the traditional one is that in late autumn or winter the collector-drainage system is closed, groundwater artificially rises up to ground level, and after 6-10 days the water is drained from the field, consequently the salt is washed away. Depending on the degree of salinity, salt washing is repeated 3-5 times, and this method gives opportunity to reduce the salt content in the medium and highly saline soils by 65-70%. It is recommended to calculate the rate of salt washing using the equation of relationship between the depth of occurrence of dissolved salts in groundwater and the coefficient of convective diffusion, which affects the reclamation condition of saline areas.

I. INFORMATION.

Improving the reclamation of saline and wetlands is an integral part of complex reclamation. Swampy, saline and highly wet areas are found in nature in the central regions of Russia, Belarus and in the south of Uzbekistan. According to research sources of Central Asia, irrigated lands are affected by salinity, plastering and swamping. It is necessary to conduct monitoring of secondary salinity areas, because the melioration condition of irrigated soils is based on data, types of salinity and salt content are taken into account, but measures against these negative processes have not been developed [1]. Lands in Mirzachol and Karshi zones were salty even before the start of their development, but it was thoroughly washed before planting. However, as a result of man-made processes during human activity, the impact on the environment is intensifying (depletion of water resources, changes of rivers and underground water quality, decrease in soil fertility), causing natural-ecological conditions and climate change [2]. Specific plans have been set for specialized organizations and researchers to solve problems in the water sector and develop innovative solutions, and they are aimed at implementing the tasks defined in the decrees of the President of the Republic of Uzbekistan for 2019-2020, as well as in other legal documents. Most importantly, it is planned to introduce new technologies, new methods and quality products in order to create a favorable innovation environment and ensure resource efficiency.

Data analysis shows that technogenic changes are multifactorial and complex due to the influence of water management (in wet areas - large construction projects) and the impact of irrigation (in dry regions). According to the studies of VNIIIGIM, UzPITI, ISMITI, ToshDAU, TIKKHMMI, one of the causes of salinization is mainly related to the improper use of irrigation water. As a result, there is a decrease in yield on highly saline soils by 80-85%, on moderately saline soils - by 30-50%, on slightly saline soils - by 10-15%.

The natural regime of groundwater and the water balance, as well as its initial methodological principles and classification of zoning, have also changed [3]. The rise of the groundwater level was mainly occured due to the redistribution of water resources. Based on the long-term monitoring data of UzDAVERKADASTR experts, along the Republic as of 01.01.2012 - 141.3 thousand ha., and as of 01.01.2020 133 thousand ha. it has been determined that there are areas affected by acute toxic salts in the irrigated land areas. However, there is a trend of year-to-year decrease of highly saline areas (in 2007 - 3.7%, in 2012 - 3.3%) and an increase of low salinity areas (from 30.9% to

31.3%), i.e. increased upto 0.4%. A slight decrease of the total saline areas by 16.2% (65.9% in 2006, to 49.7% in 2009 and 42.6% in 2019) is also observed [4].

Highly saline lands were observed mainly in the Republic of Karakalpakstan, Khorezm, and Bukhara regions. Highly saline lands in the Republic of Karakalpakstan in the composition of irrigated lands are 11.8% in 2007, 10.5% in 2012, and 9.8% in 2019. In Khorezm region - 14.1%, 13.1% and 11.25%, in Navoi - 5.7%, 4.3% and 3.8%, and in Bukhara - 4.6% on average [5].

A.K. Chernyshev and Yu.I. Shirokova mainly used traditional methods in assessing the level of seepage waters and their miniralization. Based on a long-term data analysis, it was determined and assessed by them the impact of soil salinization and their ameliorative condition to the level of seepage water, as well as the impact of changes in the miniralization of seepage water to climatic factors. This gave positive results due to the accuracy and scientific nature of scientific research [6].

Innovative, resource-saving technologies in agriculture are a set of new or improved methods and tools aimed at reducing the consumption of resources in agriculture, allowing to improve the quality of the process (product) that is in demand in agricultural markets [7]. Therefore, it is not only about solving scientific, economic and, perhaps, environmental problems, but it is also about the transition to a new modern economic system and the definition of its components. Modern irrigation and salt washing technology cannot be applied to agricultural land without conducting scientific field experiments and knowing the reasons for its deterioration.

II. MATERIALS AND METHODS

Analysis of the literature and experience of developed countries show that wherever the technical performance of irrigation systems is reached its high level, even in the conditions of global climate change, reliable productivity can be achieved [8, 9]. Followings are the stages of determining the criteria for regional assessment of potential salinity and wet level:

1. Regional and local movement of groundwater, chemical composition, depth and sources of saturation.
2. Soil type, condition and salinity level. In order to quickly and easily eliminate salinity, the source of groundwater saturation should be identified.

There is also an opportunity to use the abundance of water resources more efficiently in non-growing period than in the growing season. Regardless the use of transboundary rivers by neighboring countries (Kyrgyzstan and Tajikistan) in the energy regime, and water consumption in rivers exceeds the level of demand in the autumn-winter and spring months, the transboundary river waters in our republic are used in small quantities (12-17%). So, the non-restriction of the use of river water in non-growing season increases the possibility of salt washing of the land.

For highly saline soils, the concentration of water with mineralization mineralization 2 g/l is 3.5-5.0 times lower than that of the soil solution, and water with mineralization 3 g/l is 2.4-3.3 times less. In soils with even stronger salinity, these indicators are even higher. Thus, the water with mineralization 2-3 g/l can dissolve the salts present in the soil and is suitable for salt washing. In this case, it is necessary to pay attention to the washing properties of the soil and drainage [11].

The difference of the recommended salt washing method from the traditional one is that in late autumn or winter the collector-drainage system is closed, seepage waters artificially rise up to surface level. The field is divided into ponds, and the salts from the first snow-rain impact turn into soil solutions and accumulate on the ground based on the ion exchange law with osmotic pressure and are washed away by running water (Explanatory Dictionary of Soil Science-M. 1975) Osmotic pressure of soil solution. . [12]. The water discharged from the fields is directed through the waste ditches to the lower part of the dam installed in the drainage collector on the side of the irrigated fields. In many cases, the lack of special hydraulic structures, silting of collector-drainage networks, the wrong choice of irrigation technique elements, and over consumption of irrigation water cause soil structure disturbance and irrigation erosion. Depending on the level of soil salinity and changes in air temperature, salt washing is carried out 3-5 times in the autumn-winter months without plowing the land, while the salt content in the soil can be reduced by 60-70%. . There is a well-known ISMITI recommendation for the use of the Biosilvent ameliorant when washing heavily and moderately

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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saline soils, and before using this method, the soil is plowed to a depth (0.6-0.8 m) and the preparation is mixed [13]. By this method it is increased the duration and frequency of salts washing. Disadvantages of the method: limited area for salt leaching, lack of a collector-drainage network or its inefficiency, increase in soil alkalinity (RN) after salt leaching, salt concentration remains in the active soil depth and as a result rises up with soil capillaries during vegetation period and it suffocates the plant and negatively affects for its development, etc. The method closest to the idea of scientific research is the method based on the application of physicochemical hydrodynamics recognized in the reclamation project recommended by L. I. Shirokova. Advantage of the method: deep plowing (0.7-1.0 m) is recommended to increase the rate of infiltration and soil desalinization. Irrigation and rainfall also play an important role in salt washing. In addition, changes in soil composition prevent the rise of salts into the upper layers preventing the accumulation of salts in the plant root zone [14]. The disadvantage of the system is that there is no need to flush the salts from the soil completely. Because the water supplied above the soil in order to reduce the flushing time dissolves the salts contained in the soil and adds them to the groundwater, and during the growing season, the salts rise again and cause a decrease in yield. It has been proven that the traditional method of salt washing is not fully effective on medium and highly saline lands, since the composition of salts changes and their concentration increases every year after salt washing [15].

As a result of anti-salinization measures, salt suppression in groundwater occurred, and vegetative irrigation caused the restoration of salts. Land reclamation methods turned out to be ineffective, especially in areas with large slopes and deep groundwater.

Salt balance calculations in the experimental field show that in the version of irrigation with river water (control), the mineralization of the irrigation water was 1.15 g/l. In the irrigation with seasonal irrigation norm (equal to 3970 m3/ha), 6.33 t/ha of salt additionally came to the field. During the season, it was carried away 4.2 t/ha of salt through open collector canals [16]. Thus, 2.13 t/ha of salt accumulation was observed in the field every year.

III. DISCUSSION OF THE OBTAINED RESULTS.

The difference of the recommended salt washing method from the traditional one is that in late autumn or winter the collector-drainage system is closed, groundwater artificially rises up to ground level. It is known that the productivity of irrigated areas mainly depends on the increase in the concentration and composition of toxic salts in the part of the root layer of soil rich in nutrients, as well as the depth of groundwater. Depending on the ratio of ions in the soil, salinization is divided into 4 types: chloride, sulfate-chloride, chloride-sulfate and sulfate salinization [17]. Due to the salinity of the seepage water, chloride-sulfate salinity in newly developed lands may subsequently change into chloride salinity as dissolved chloride rises to the top and accumulates on the soil surface. It is not recommended to wash heavy soils with water with a mineralization of 2-3 g/l, since the water evaporates and causes an increase in soil salinity. In order to reduce salt washing time, water that applied above the soil, like to the salt flushing method, dissolves the salts in the soil and adds it to the groundwater, and these salts rise again during the growing season and cause a decrease in productivity. While it is understood that there is no necessity removing salt from the soil completely. Lands requiring salt washing with an amount of 10,000 - 14,000 m3/ha should be leached and cleaned during the autumn-winter period. Washing salt in slightly saline lands is allowed in early spring. It is desirable to carry out salt washings with a volume of 4000 - 4500 m3/ha under the conditions of the existing vertical and horizontal drainage systems.

It is necessary to provide for additional shallow (0.8-1.2m) temporary drainage during salt washing in large and difficult-to-irrigate lands. The most important here is the effective use of drainage systems, which used to protect against seepage water in irrigated areas, their use to lower the level of seepage water (SWL) and the use of groundwater when washing salts for dissolving salts in the soil allows achieving economic efficiency. According to the experience conducted in the Kashkadarya region in the 1993s, 3.7 t/ha of salt was annually washed down from the aeration layer, and in the last 2010-2017, on the contrary, it was estimated that 8.2-11.1 t/ha. /ha of salt rose up from the seepage waters to the upper layer (data from D. Kuvvatov) [18]. Therefore, based on the law of convective diffusion it has been proven that salts rise to the ground surface level with groundwater 2.2-3.2 times more.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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When designing capital washing of salts, in most cases, the norm is set at 10-30 thousand m3/ha or more. In practice, salt washing norms (at salt washing areas of 0.15-0.25 ha) are 2000-2500 m3/. If there is a compacted layer under the plowed layer, if it is not deeply plowed and not damaged, the norm can be increased to 3000-4000 m3/. It is accepted on medium and highly saline soils, the number of salt washings to be 5-6 or more times with an interval between them from 10-15 to 30 days.

Table 1
Calculated results of salt leakage from secondary highly saline lands

№	Experiment option	Soil thickness, sm	Salts dissolved in water, t/ha		Discharged salt, compared to the initial amount, %
			Before salt washing 1)	After salt washing 2)	
1	Traditional salt washing	0 – 50	33,0	26,0	21,21
		0 – 100	100,0	69,0	31,0
		0 – 150	162,0	105,0	35,18
2	After water discharge (estimated)	0 – 50	33,0	19,0	42,42
		0 – 100	100,0	71,0	29,0
		0 – 150	162,0	122,0	24,69

Note *: 1) regarding the data of Table 1;
2) – V.R. Calculated based on the Volobuev formula

Table 1 shows that in the 50 cm deep layer, 21.2% was achieved by the traditional method of salt washing, and 42.4% was achieved by the method of salt washing by running water, that is, two times more salts were washed. The amount of washed salts in soils with 0-100 cm and 0-150 cm depth is equal to each other, which indicates that nutrients washed away from the layer where the root is located and fell into seepage waters. The main purpose of this is to dissolve the salts contained in the soil before the air temperature cools and bring them to the surface under the influence of rising ground water. The aeration layer is completely wetted and salts accumulate on the surface due to capillary rise and evaporation. First, the ponds in the upper part of the field are filled with water, and then the next ponds are filled. Water should not exceed the walls of ponds. (Figure 1).

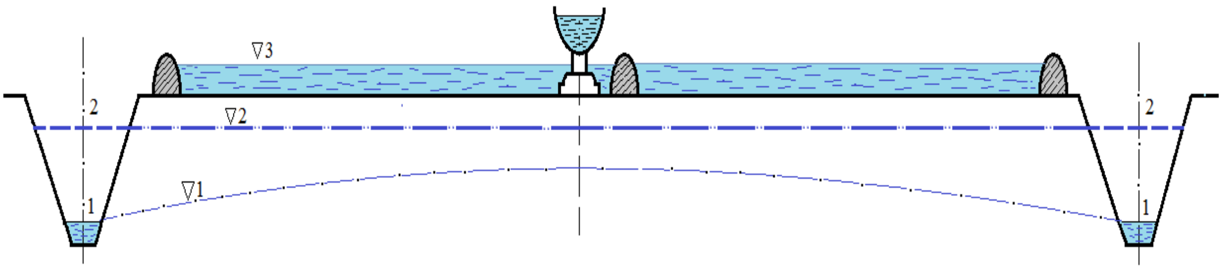

Figure 1. Cross-section of the brine area
1 - groundwater level in its natural condition;
2 - groundwater level water at rised condition;
3 - water level in ponds during salt washing.

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International Journal of Advanced Research in Science, Engineering and Technology
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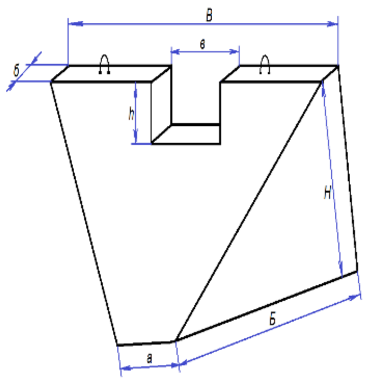
The total volume of water used for washing salt was equal to 8500 m3/ha when calculated by Volobuev's formula [19]. On the other hand, field work may take longer and require a lot of work. At each irrigation ther arise the conditions for salt from the upper soil layer to washed down into the lower layer.
The period of salt flushing is moisture charging, which is carried out in late autumn or in December-January, if the soil is less salty, then in late February and early March. On moderate saline lands, salt washing can be carried out from December to March, But if the area is not provided with drainage networks (due to stagnation of seepage water and its surface location), it is advisable to start salt washing process earlier. Because the late start of salt washing causes still high humidity at the time of sowing (tillage is not achieved and it is delayed) [20].

Discharge of water from ponds carried out in 2-3 cycles in December-February when there will be more water in the river and canal. Water in dams in collector drainage system open up from the down to up at the end of February. The best option for a dam is a monolithic concrete structure. Its dimensions shown in Figure 2 are made by measuring the cross section of the channel of the blocked part of the collector drainage.



a = 1÷2 m width of fence bottom, corresponding to width of the collector;
B = (2÷3) a - width of fence bottom;
b = width of upper part of fence 0.2÷0.5 m;
V= Vcollector - width of fence, corresponding to width of collector top;
Z - width of water passage;
h - depth of water passage;
N - 2÷3 Ncollector - fence height;
Ncollector - collector depth

Figure 2. barrier structure made by monolith concrete

It is possible to reduce the seepage water by plowing the ground deeply (0.8-1 m). As a result, seasonal snow and rains have a good effect on desalination of the land. In practice, this technology is implemented in the following stages:

The attenuation of water in the collectors and the rise of seepage water in the fields are observed within 1.5-2 months. However, the rise of moisture and dissolved salts in saline fields depends on the mechanical composition of the soil and the magnitude of the salt concentration. Soil temperature affects the minimum moisture capacity. At the same time, the highest humidity, the ability to retain moisture and the criterion for assessing the state of the soil are the criterion for the capillary draft of moisture in the soil by salts. According to international critical tables, the relationship between surface absorption and external temperature is expressed by the following equation:

$$Gt = 117 - 0{,}152T ,$$

Gt is expressed in dynes/cm and temperature T in kelvins. Because of the increase in temperature from spring to summer, soil moisture capacity decreases at a depth of 15-30 cm of the soil layer during the growing season. After that, the lands allotted for ponds are flooded and salt is washed from top of the field to way down in turn (similar to the distribution of water for rice).

Water is distributed from the middle of the field to both sides with the help of a ditch. A drain pipe is installed behind the lowest fence from the ponds, and the water flowing out of every 2-3 checks is drained into a collector. After a few days, the barriers in the collector are removed from the bottom up.

In practice, to prevent erosion of the banks of the collector before opening the barriers, it is advisable to release a small amount of standing water in the collector. Because, if a sharp drop in the water level in the collector occurs it is observed that seepage waters by returning to the collector wash away the banks and destroy them.
Summary

ISSN: 2350-0328
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IV.SUMMARY

1. For the conditions of the southern soil-climate of Uzbekistan (in light gray soils of medium and high salinity desert zone), the theoretical development of the method of raising the seepage water of the secondary saline soils to the surface by moistening the collector-ditch water and draining water from the deep soil saline floors is recommended. With this method, after harvesting, without plowing the land, preparatory work is carried out to supply moisture-charging water through ponds (salt leaching rates are 5000-7000 m3/ha, depending on the mechanical properties of the soil, water supply is stopped after 6-10 days).

2. It is recommended to continue washing the soil after winter snowfalls and rains. This plays an important role in improving the reclamation state of lands. As a result of changes in temperature and soil composition, salts rise to upper layers of earth with seepage waters, where they dissolve salts in the soil and thus eliminate the accumulation of salts in the root zone of plants.

3. Salt leaching should be carried out in conjunction with other hydro-reclamation, agrotechnical and agrochemical measures. If the soil has a high level of salinity, it is better to water it in late autumn or in December-January, if it is less saline, then in late February-early March. After the supply of moisture-charging water in 3-4 cycles, it is necessary to sharply reduce the level of seepage water, because before plowing (March 10) the land must be brought to a normal state just before sowing period i.e. April 5-10.

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