The Mathematical model for determining the value of flushing rates for desalination of saline soils

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Abstract. The article presents formulas for determining the value of leaching rates for desalination of a meter (root inhabited) layer of soil, which is characterized by different mechanical composition and salt release properties, and the formula which is used as the basis for calculating leaching of saline lands is the theory of physicochemical hydrodynamics based on the equation of convective diffusion and mass transfer of conditions of unsteady soil water regime. The formulas take into account the movement of moisture in the soil of dissolved salt, which moves due to the difference in the concentration of the soil solution. If moisture in the soil moves, then the salts move in it not only due to the difference in concentration, but also due to their transfer by water (convective component). This process is called convective diffusion, which is taken into account by the D* coefficient, which changes at filtration rates within wide limits (1-10) 10^{-3} m^2/day. One of the topical issues is the development of a mathematical model, to quickly and accurately determine the value of the leaching rate for specific soil-reclamation areas, taking into account the estimated desalination depth, the texture and porosity of the soil, the actual speed of water movement through the soil pores, the degree of salt release, the salt transfer parameter (coefficient convective diffusion), also the initial soil salinization, irrigation water salinity, etc.

Keywords: leaching rate, soil salinity, initial salt content, convective diffusion, desalination.

Introduction. In the draft of the Cabinet of Ministers of the Republic of Uzbekistan dated 02/09/2021 on "Improving measures for leaching in the cultivation of agricultural crops", it is noted that the total irrigated area in the republic is 4.3 million hectares. As of October 1, 2020, 44.7% of irrigated lands are saline to varying degrees, including: slightly saline lands - 31%, moderately saline - 11.9%, highly saline - 1.9% [1]. The project also indicates that due attention is not paid to the preparation of lands for leaching and systemic organization of leaching works, to the quality of these works and regular monitoring of water consumption. As a result, in farms, dekhkan farms and agricultural clusters located, especially in the northern regions of the Republic of Karakalpakstan, in many districts of the Jizakh and Syrdarya regions, as well as Bukhara, Navoi, Fergana and Khorezm regions, agrotechnical rules and timing of leaching operations are grossly violated, and water losses are allowed. and the efficiency of washing operations remains at a low level [1].

The main part of these lands belongs to the hydrogeological zone, called - the zone of dispersion (evaporation) of groundwater. Vast areas of land are located in the middle and lower reaches of the large rivers Amu Darya and Sir Darya. as well as in the flat deserts of Kara kum and Kizil kum. Here, the slopes of the earth's surface, aquifers and impermeable horizons, as well as the surface of groundwater are insignificant and fluctuate within 0.0002-0.001. The upper stratum of fine earth extends to a great depth. Soils are represented by smaller mechanical fractions and are usually characterized by a large water-lifting (capillary) capacity. Drainage layers (pebble, gravel, sand) are either absent or lie at great depths (15-30 m and more).

On irrigated lands, groundwater occurs more often at a depth of 1-3 m, on non-irrigated (fallows, fallow lands, virgin lands) - at a depth of 5-10 m and more. In some low places, groundwater can wedge out to the surface, where wetlands are formed [5]. Groundwater and filtration surface water entering this hydrogeological zone replenish the groundwater. The latter are consumed over a large area for evaporation and transpiration and, as it were, dispersed in space. The combined action of the above natural factors adversely affected the land reclamation state. In a hot climate and well-pronounced capillary properties of soils, with a high (1-3 m) occurrence of saline, stagnant groundwater, they are intensively spent on evaporation. Water evaporates, and salts, gradually accumulating, saline the soil. As a result, the lands of this hydrogeological zone, by their natural conditions, are a zone of saline lands. However, when carrying out the necessary reclamation measures, the basis of which is leaching against the background of drainage and the introduction of water-saving irrigation technologies, these lands will be salted and cultivated.

The efficiency of leaching depends on the water-physical properties of the soil, the degree of its salinity and the depth of the groundwater. It is carried out by supplying a certain volume of water (leaching rate) to saline lands, which dissolves salts and displaces them in the form of a solution into groundwater, intercepted and discharged by the drainage network. The works of many scientists, such as V.R. Volobuev, N.D. Kovda, N.G. Minashina, A.N. Kostyakov, S.F. Averyanov, A.E. Nerozin, are devoted to the issue of the process of washing saline lands and carrying out leaching irrigation. [2,3,7,8,10,11,12].

Research methodology. To determine the leaching rate in drained areas, the formula of V.R. Volobuev is most often used [2]:

$$M = 10000 \cdot \alpha \cdot \lg \frac{S_N}{S_D} \qquad m^3/ha$$

where: α is the salinity index of soils $\alpha = 0.62 \div 3.3$, S_N and S_D are the initial and permissible salt content in the washed layer,% taken from Table 1. This dependence makes it possible to find the value of the leaching rate for desalination of a meter layer of soil.

Table 1. Permissible salt content for medium-salt-tolerant agricultural crops, % of dry soil mass.

Salinity type	Acceptable salt content		
	Dense residue	Cl'	SO"$_4$
Chloride	0,2	0,01-0,03	-
Sulfate chloride	0,3	0,01-0,03	0,04
Chloride sulfate	0,4	0,01-0,03	0,19
Sulfate	1,0	0,01-0,03	0,82

Flushing can be effective if the drainage of flushing water outside the massif is provided. As a rule, saline lands have insufficient natural drainage, and permanent drainage is built on them to prevent secondary salinization and waterlogging [5]. Typically, its capacity is calculated for the load of the operating period, as a result of which the throughput of this drainage is insufficient to remove flushing water at a given rate even with increased heads on the inter drain. Consequently, for the period of leaching, permanent drainage must be supplemented with temporary drainage, made in the form of open channels with a depth of about 1 m, at a distance of 20-50 m from each other [6].

The duration of leaching depends on the permeability of the upper soil and ground layers and on the drainage parameters. The duration of the flushing is set using technical and economic calculations, taking into account the costs of flushing (payment to irrigators, the cost of preparatory work), temporary drainage devices, temporary irrigation ditches, for the construction of an additional irrigation network, when the permanent network is insufficient to supply the flushing rate at the specified time. The optimal wash duration is considered with the minimum total costs [9].

During the flushing period, it is necessary to monitor compliance with the flushing standards, and after its completion, conduct a continuous salt survey in order to establish the degree of flushing and identify under washed areas. Monitoring of the level and chemical composition of groundwater should also be organized. In areas with poor water permeability, it is advisable to combine washing with rice cultivation.

On the farm, leaching is planned so that large areas are simultaneously washed in concentration. The area of simultaneous flushing is determined by the capacity of inter-farm and intra-farm canals. Washed lands must be reclaimed immediately, using, if necessary, sowing salt-tolerant cultivators and prescribing a flush irrigation regime to avoid salinity restoration [3]. After washing, it is advisable to carry out deep plowing, apply organic fertilizers and sow crops with a powerful root system, preferably alfalfa.

In recent years, a number of new methods of reclamation of saline lands have been tested. In particular, the effectiveness of the use of water for flushing, pretreated in a magnetic field (magnetic melioration), is being studied. At the same time, the solubility of salts in the soil increases significantly, which contributes to a reduction in the duration of leaching. When washing soils with magnetized water with mineralization up to 1 g/l, additional salt removal was, in experiments, 10-20%. The combined effect of a magnetic field and a chemical ameliorant (sulfuric acid) turned out to be especially effective: the filtration coefficient increased eight to ten times, the removal of salts by 40% [3,4].

In addition to the ameliorative effect on the soil, the magnetic and electric fields increase the field germination of seeds and accelerate the receipt of seedlings, which contributes to an increase in the yield of agricultural crops.

In recent years, the theory of physicochemical hydrodynamics has been taken as the basis for calculating leaching of saline lands [3,5]. In this case, the basic equation of convective diffusion and mass transfer of salts for the simplest case is as follows:

$$\frac{dn}{dt} = D \cdot \frac{d^2 n}{d^2 x} - V \cdot \frac{dn}{dx}$$

where: t-time, x-distance from the soil surface, D-salt transfer parameter, n is the salt content at point x, V is the actual speed of water movement through the pores of the soil. Based on this equation, for steady-state conditions, the dependence for the first stage of washing was derived, and then S. F. Averyanov proposed an equation for determining the washing rate [9]:

$$M = 10000 \cdot (2 \cdot A \cdot \sqrt{D \cdot t} + x) \cdot m$$

where: x is the calculated desalination depth, m, t is the leaching duration, days, m is the porosity of the soil in fractions of the volume, A is the parameter depending on the initial salinity of the soil, the salinity of irrigation water, etc.

If moisture in the soil moves, then the salts move in it not only due to the difference in concentrations (diffusion component of the salt flow), but also due to their transfer by water (convective component). Such a process is called convective diffusion, which in the equation of S.F. Averyanov is taken into account by the coefficient D, which changes at filtration rates characteristic of capital leaching in the range of (1-10) 10^{-3} m^2 / day.

Results and discussion. As a result of compiling a mathematical model of formulas, which takes into account the degree and type of salinity, porosity, salinity of soils, the salt transfer parameter, the actual speed of water movement through the pores of the soil, the convective diffusion coefficient, which varies within 0.001-0.01 m^2 / day depending on the speed the movement of rinse water, you can quickly determine the value of the leaching rate.

On irrigated lands, after harvesting, a salt survey is carried out and for each specific soil - reclamation, hydrogeological conditions, the value of the leaching rate for desalination of a meter layer of soils is determined.

Before carrying out flushing, preparatory work is performed: surface leveling (permissible deviation of the earth's surface in checks from the average mark no more than ± 5 cm), deep (25-30 cm) plowing, cutting of transverse rollers to form checks. The dimensions of the rolls are related to the distance between the drains. If, by the time of leaching, a permanent closed horizontal drainage is built, over the drain strip, 2-3 m wide, must be fenced with rollers and not washed in order to avoid erosion of the drainage backfill and silting of drains. Then temporary drains and temporary sprinklers are cut, longitudinal rollers are arranged from the excavated soil along the drains and sprinklers. Flushing is carried out on receipts ranging in size from 17x50 to 50x500 m, enclosed by rollers with a height of 0.4-0.6 m, without bypassing water from the receipts and without dumping. If flushing is carried out without drainage, large checks are used (1-3 hectares), the height is assigned 1-1.5 m (they are poured using bulldozers).

Temporary sprinklers are laid so as to ensure the supply of water to each check. The flow rate of the sprinkler should be 50-100 l/s, the excess of the water level in it above the surface of the checks is at least 20-30 cm. In the head of the temporary sprinkler, water outlets are arranged, equipped with water meters.

Temporary drains with a depth of 0.8-1 m discharge water into canals 1-1.2 m deep. The width along the bottom of drains and canals is taken as 0.2-0.5 m, depending on the parameters of earth-moving equipment, and the laying of slopes is 1:1.At the end of the flushing, the temporary network is leveled and re-graded.

During the flushing period, it is necessary to monitor compliance with the flushing standards, and after its completion, conduct a continuous salt survey in order to establish the degree of flushing and identify under washed areas. Monitoring of the level and chemical composition of groundwater should also be organized.

The C ++ algorithm for solving this problem is as follows:

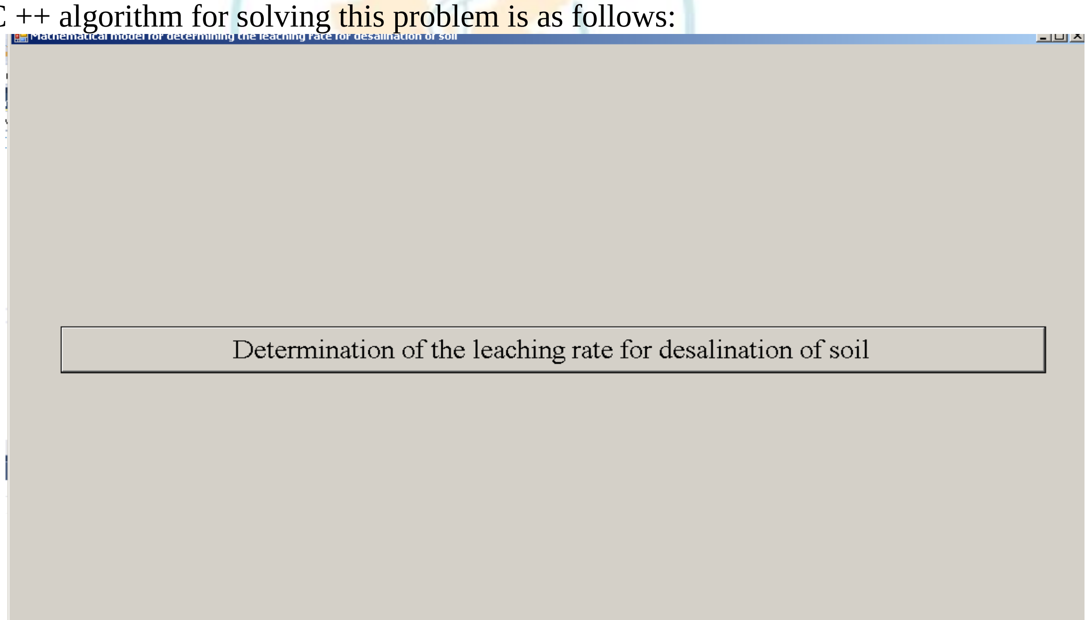

Fig 1. The initial window of the program.

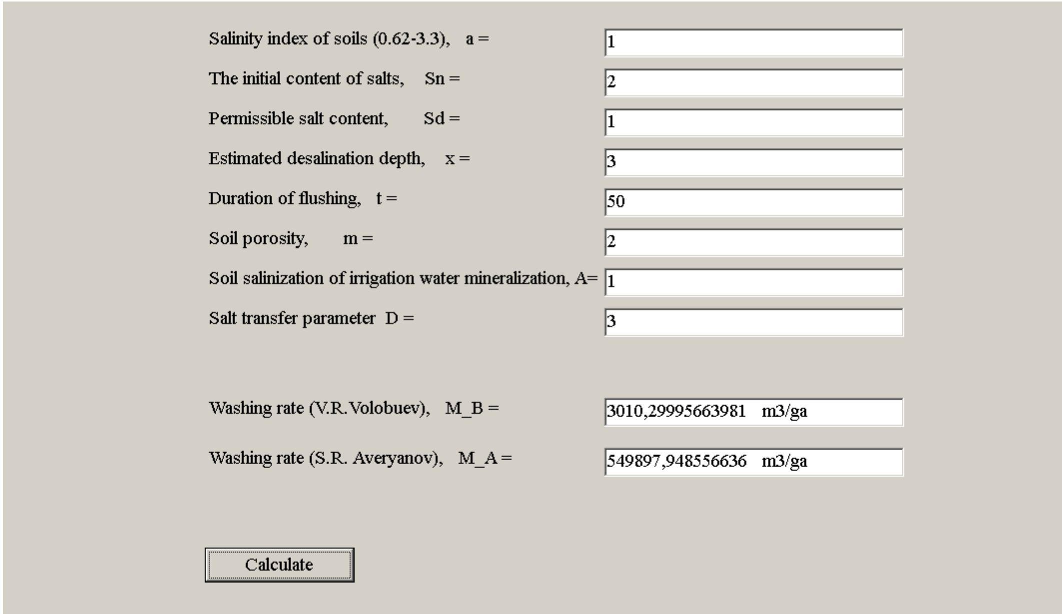

Fig. 2 The result of the calculation.

Conclusions.

1) As a result of the program, the value of the leaching rate will be determined for soils of different degrees of salinity.

2) The value of the leaching rate for desalination of a meter layer of soils to the permissible salt content is determined.

3) The diffusion of anions and cations in the soil solution is taken into account depending on the concentration due to their transfer along with the wash water.

4) According to the mathematical model, the calculation is carried out for various soil-climatic and hydrogeological conditions of saline lands with different degrees of soil salinity.

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