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The Research of the Ground Water Supply Process on Irrigated Soils at Various Flushing Technologies

Seitkaziyev Adeubai, Shilibek Kenzhegali, Salybaiev Satipaldy, Seitkaziyeva Karlygash and Zhumadilova Anar

Department of Ecology, Faculty of Water Resources, Environment and Construction, Taraz State University Named after M.Kh. Dulaty, Taraz, Kazakhstan

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Abstract: Soil flushing is one of the essential elements to maintain the water-salt balance in the arid zone land irrigation. Currently there are estimated and recommended flushing rates for different soils. To improve the flushing efficiency and economy of irrigation water it is necessary to study the mechanism of soil desalination while flushing. This paper proposes the method for calculating the rate and extent of soil desalination based on the analysis of the salt particles motion. Thus the basic estimated element is the speed and driving range of the salt particles in solution. This method allows defining and justifying the saline soils cycle flushing technology.

Key wards: Soil · Analysis · Water-salt

INTRODUCTION

Efficient use of water and land resources is directly dependent on the technical condition of irrigation systems, which determines the overall environmental situation and causes the sound environmental management on the reclaimed lands. In other words, environmental condition and reclamation of irrigated lands is in close connection with the factors of optimal control of both natural and technological (anthropogenic) processes. Therefore, the cultivation of high and stable yields of agricultural crops on irrigated lands to a large extent depends on their efficient reclamation. Practice shows that yield losses in irrigated areas with poor reclamation condition can reach 20-30 or even 50%. Hydrogeological and reclamation situation on the irrigated lands is determined by a complex of factors, the main of which are the depth of the ground water and their salinity, the extent and nature of the aeration zone soil-ground salinity, the irrigation networks technical condition, etc.

One of the main areas of irrigated agriculture development in the country is the Shu-Talas River Basin. Natural and climatic conditions and human resources of the region are favorable for growing valuable technical, grain, vegetable and other crops, to develop forage for livestock. Large cooperatives, peasant and individual farms specializing in production of agricultural products are organized there now.

However, the condition of irrigated agriculture in recent years, is characterized by significant changes: the deteriorating technical level of drainage and water facilities, reducing reclamation of irrigated lands and a significant loss of irrigated areas which are in use.

A significant factor in increasing the productivity of irrigated lands is the development and implementation of evidence-based agrotechnical, reclamation and hydrotechnical activities.

The aim of the research to improve soil and ecological condition of the land resources of the irrigation system and irrigated farming by restoring and enhancing the productivity of saline and alkaline land with the use of agrotechnical and hydromeliorative techniques.

Ecological condition of the researched irrigated areas depends on the hydrochemical regime of water sources, farming system and is determined by the factors of optimal management of natural and anthropogenic

Corresponding Author: Seitkaziyev Adeubai, Department of Ecology, Faculty of Water Resources, Environment and Construction, Taraz State University Named after M.Kh. Dulaty, Taraz, Kazakhstan

processes. Regulation of gray- meadow and meadow-gray strongly salined soils of chloride-sulphate salinity through the process of control of groundwater recharge processes by means of channels filtering, determining the mechanism of salts movement in the soil with the use of the technological scheme of flushing, setting the allowable salt content and evaporation from the groundwater surface will serve as a basis for rational nature use as it ensures environmental sustainability of geoagrolandscapes and creates favorable conditions for long-term use of natural resources without their depletion, degradation and pollution.

MATERIALS AND METHODS

To justify the quantities of the saline soils flushing rates, as well as to study the dynamics of salts flushing the experiment in the saline soils flushing was done on 5 sites. Experimental sites were laid after the completion of soil-reclamation assessment. While selecting the sites such characteristics as the soil cover and the type of salinization were taken into consideration. The experimental work in saline soils flushing began in June 25 and finished in September 5, 2012. The sites with the size of $10m^2$ were chosen to research the saline sites flushing outcomes. Before flushing the soil surface was loosened to a depth of 30 cm. The flushing was done in cycles, normally 1500-2000 m^3/ ha each. Before flushing and after each flushing cycle the mixed samples from the site were taken from three replicates to determine salinity. The samples were taken using a hand drill every 20 cm till depth. After the selection of the sample the wells were swabbed.

To flush there be used water from an artesian well with salinity of 0.5 g per liter, of hydrocarbonate-sulphate, magnesium and sodium-calcium type (the dominant ion is given last) PH 7.57 [1-3].

Next to the site designed for the saline soils flushing there were studied water and physical properties of soils-grounds. There were determined such features as density, natural moisture, mechanical properties and permeability of soils.

The first experimental site was laid on a salt meadow marsh. The salinity type by the anion composition - sulfate by the cation sodium. The average salt content in the first layer is 0.850. Groundwater depth - 2.5 m. Lithological structure of the profile: the first meter - medium and heavy clay loams, the second meter and below - light clay loams. Water permeability is very low. To absorb the first 20 cm of water 155 hours required, the second layer of 20 cm - 450 hours. Totally, it took 600 hours to pass 40 cm of water through the soil layer. So we had to restrict ourselves to two cycles of flushing.

The second experimental site was laid on the meadow-gray soils of high salinity. The type of salinity - chloride-sulfate, sodium. The average salt content - 1.75 % in a meter layer. Groundwater depth - 3.2 m. Lithological structure of the aeration zone: middle clay loams - up to 137 cm and sandy loam – below up to sodium. Water permeability is low. To absorb the normal amount of water (20 cm layer) in the first flushing cycle 6 hours required, in the second flushing cycle - 55 hours, in the third flushing cycle -180 hours, in the fourth flushing cycle - 240 hours. Totally, it took 540 hours to pass 80 cm of water through the soil layer.

The third experimental site was also laid on the meadow-gray soils of high salinity, but the type of salinity sodium sulfate. The average salt content is 1.40 % in a meter layer. Groundwater depth - 3.4 m. Lithological structure of the aeration zone is characterized by a predominance of layers of light mechanical composition (light clay loams, sandy loams). Water permeability is low, but a little better than of the soils on the previous site. To absorb the normal amount of water (20 cm layer) in the first flushing cycle 6.5 hours required, in the second flushing cycle - 30 hours, in the third flushing cycle -90 hours, in the fourth flushing cycle - 140 hours, in the fifth flushing cycle – 174 hours. Totally, it took 480 hours to pass 1 m of water through the soil layer.

The fourth experimental site was laid on the meadow and marsh deserting soils of high chloride-sulfate, calcium-sodium type of salinity. The average salt content is 1.80 % in a meter layer. Groundwater depth - 2.7 m. Lithological structure of the aeration zone is characterized by a light mechanical composition on the top (0- 53 cm) and a heavy one in the bottom (heavy clay loams, clays).

Water permeability of the soils is consistently high. To absorb the normal amount of water (20 cm layer) in the first flushing cycle 2 hours required, in the second flushing cycle - 2 hours, in the third flushing cycle – 2.5 hours, in the fourth flushing cycle – 3.5 hours, in the fifth flushing cycle – 3 hours. Totally, it took 11 hours to pass 1 m of water through the soil layer.

The fifth experimental site was laid on the meadow-gray solonchak- alkaline soils of sulfate-chloride type of soda salinity, sodium type of salinity. Flushing here will

Table 1: The Change in Soil Salinity in the Flushing Process (in the meter layer)

Soil	Flushing rates m^3/ha	Salination type	Salts content, %	Ions, mg/eqv						
				HCO'_3	CO_3	Cl'	S''_4	Ca''	Mg''	Na+''
Meadow solonchak	Before flushing	Sulphate-sodium	0.78	1.1	2.81	2.2	5.5	0.24	0.20	11.2
	2000	Sulphate-sodium	0.44	0.9	1.73	1.5	2.5	0.15	0.14	6.4
	4000	Chloride-sulphate	0.4	0.8	1.6	1.4	2.2	0.16	0.13	5.6
Meadow-gray soils of high salinity	Before flushing	Chloride-sulphate	1.6	0.4	0.06	9.3	14.3	3.6	2.45	18
	2000	Chloride-sulphate	1.1	0.6	0.22	6.3	9.85	1.86	1.77	13.4
	4000	Sulphate-sodium	0.74	0.7	0.25	1.7	8.15	3	0.85	6.9
	6000	Sulphate-sodium	0.44	0.8	0.30	1.2	4.1	0.6	0.2	5.6
	8000	Sulphate-sodium e	0.38	1.3	0.17	0.51	3.4	1.70	0.6	3
Meadow-gray soils of high salinity	Before flushing	Sulphate-sodium	1.3	0.6	0.58	2.7	14.6	0.50	0.4	17.5
	2000	Sulphate-sodium	0.7	1.1	0.97	1.2	6.2	0.4	0.23	8.8
	4000	Sulphate-sodium	0.8	1.2	1.1	0.7	7	0.43	0.35	9.31
	6000	Sulphate-sodium	0.47	1.5	1.2	0.52	3.55	0.33	0.26	6.2
	8000	Sulphate-sodium	0.30	1.3	0.98	0.45	1.7	0.240	0.20	3.9
	10000	Sulphate-nitro	0.26	0.9	0.96	0.31	1.6	0.204	0.160	3.4
Meadow and marsh deserting soils of high salinity	Before flushing	Chloride-sulphate	1.7	0.3	0.00	8.2	17.0	6.5	4.5	14.6
	2000	Chloride-sulphate	1.5	0.3	0.00	6.5	15.7	7.4	3.14	12
	4000	Chloride-sulphate	1.7	0.4	0.00	8.0	18.4	7.9	5.4	13.41
	6000	Sulphate-sodium	1.1	0.4	0.00	1.1	14.1	7.4	2.3	6
	8000	Sulphate-sodium	0.71	0.5	0.00	0.99	8.85	4.1	1.76	4.56
	10000	Sulphate-sodium	0.9	0.6	0.00	0.62	12.25	5.66	2.140	5.65

be later (October, 20), but before the beginning of winter and freezing of water on the experimental site did not give the chance to change the salinity rate during flushing. Therefore, the report does not contain data on the salt loosing on the experimental site No. 5.

Table 1 shows the change of soil salinity during flushing. As we see the largest amount of salts is deleted from the meter thickness of the ground-soil on the experimental sites, where there are a lot of the easily soluble salts of chloride and sodium sulphate. Salts are less removed from the soils of the site 4, which have a significant amount of sparingly soluble calcium sulfate.

The second meter of ground-soils shows the increase of salts content at the beginning of flushing due to the salts leaching of the top meter layer. There is also further leaching of the second meter soil layer.

During flushing, along with the change in the degree of salinity, the chemistry of salinity also changes. The soils of the experimental site 2, of the sodium chloride-sulfate type, result from the removal of soluble chloride and sodium sulfate.

RESULTS AND DISCUSSION

Soil flushing is one of the essential elements to maintain the water-salt balance in arid zone land irrigation. Currently flushing norms are calculated and recommended for different types of soils. However, these calculations are mainly based on experimental data. To improve the flushing efficiency and economy of irrigation water it is necessary to research the mechanism of soil desalination while flushing.

The goal of the research is the development of environmental regulatory frameworks of meadow-gray soils with chloride-sulphate salinity taking into consideration the current flushing technological schemes, which provide desalination of the ground-soil root zone.

The article describes soil- ecological, climatic, hydrological and landscape conditions of the tested irrigation area. It also presents water and physical properties of the different sub-types of saline soils: ordinary gray soils, gray-meadow and meadow-gray. The climatic conditions of the studied object are characterized with continental features and aridity. Summer is hot, winter is moderately cold and mild, wet years are followed by dry periods with bursts of drought and dry winds. Wind activity is often accompanied by snow and dust storms, especially in the plains.

Hydrogeological conditions are characterized by the presence of several hydraulically connected aquifers, confined to alluvial medium and upper quaternary sediments and separated by impermeable layers and lenses of clay loams and clays. Groundwater of the upper aquifers is subterranean on bedding conditions and of the lower ones – pressure.

Groundwater is preferably fresh (up to 1 g/l) and brackish (1-3 g/1) by salinity. At some sites there is brackish groundwater with the salinity of 5-10 g/1. In a single case in the west central part of the irrigated area there is salted water with the salinity of 9.5-10.8 g/l [6-13].

Parent material for them are the forest clay loams and alluvial-layered deposits, where the rocks of different lithological structure - sand, sandy loam, clay loam, clay are interbedded.

In the large flat reductions with the groundwater depth of 1.5 ... 2.5 m there are gray- meadow soils, mainly of heavy clay loam mechanical composition. Alluvial-meadow soils are found in the flood plain of Talas River and their mechanical composition – light clay loam at the depth of 80-100 cm are underlain by gravel and pebble deposits. The research considers the processes of filtration water movement (with the flushed checks), occluded to groundwater. On the background of deep tillage with different drain space and depth the following objectives were reached:

- There were determined filtration losses from the flushed check in the expenditure of groundwater through evaporation considering the depth of groundwater levels and the lack of groundwater outflows;
- There was defined the involvement of groundwater and their effect on filtration from the flushing check.

The total area of the experimental site was 2 hectares. The flushing options normally 4000-10000 m^3/ha have been researched for three years. There were explored the options of the single irrigation rates (1500-2000 m^3/ha), transported to the checks.

Considering that under continuous flooding groundwater surface often comes up to the earth surface, we research backed filtration in this article, i.e. filtering, in which the seepage water from the experimental site merges with the groundwater.

We believe that the groundwater flow decline at the distance dr is caused only by evaporation, so we have [3-11]:

$$-\frac{\partial Q}{\partial r}dr = 2\pi r?\,dr \text{ or } Q_x = \sqrt{k \cdot H_s \cdot h_k \cdot E} \cdot ?^{-R\sqrt{A}} \qquad (1)$$

where Q - filtration rate, r - distance from the check center, E - the evaporation rate, which, depending on the groundwater depth is expressed by the following S.F. Averyanov's equation [3-5]:

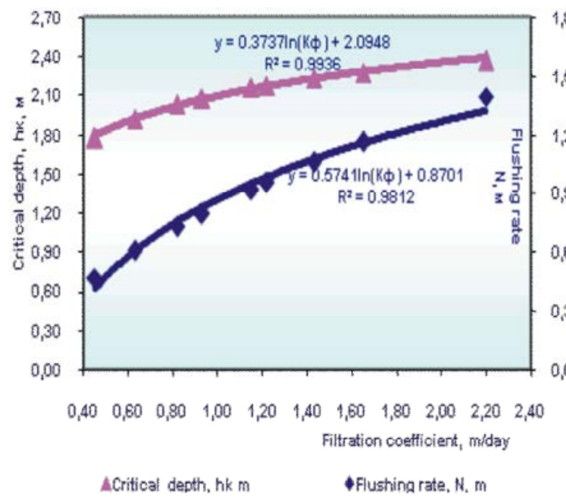

Fig. 1: The dependence of the groundwater flow rate from the filtration coefficient and the critical depth (Option 1)

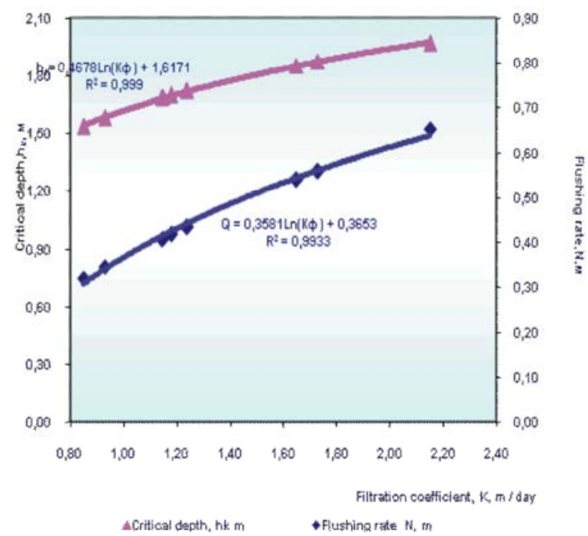

Fig. 2: The dependence of the groundwater flow rate from the filtration coefficient and the critical depth (Option 2)

$$E = E_0\left(1 - \frac{h}{h_k}\right)^n \qquad (2)$$

where h_k - critical depth of groundwater levels where a significant water expenditure to evaporation begins, E_0 - evaporation rate from the soil surface at a very high groundwater level, n - the exponent (1<n<3). According to the monolithic research data there was made a diagram of dependence of the groundwater flow rate from the filtration coefficient and the critical depth (Figures 1, 2).

Table 2: Calculation of the groundwater recharge due to filtering from the channels

Options	Distance between loosening b, m	Length of the strip I, m	Distance of the drain from the check center R, m	Ground water level h, m	Capacity of the aquifer to water pressure H_s, m	Power of the ground water flow T, m	Filtration coefficient K, m / day	Evaporation rate E_0, m / day	Evaporation rate from the surface	Critical depth h_k, m	Groundwater flow rate Q, m / day	Drainage water Д, l/s	Flushing period t, day	Flushing rate N,м
I	0.5	20	40	3.0	33	30	0.45	0.007	0.0001704	1.77	0.31	0.910	60	0.472
			40	3.0		30	0.63	0.007	0.0001235	1.92	0.40	1.168	60	0.606
	1.0	20	40	3.0		30	0.82	0.007	0.00009485	2.03	0.49	1.408	60	0.730
			40	3.0	33	30	0.93	0.007	0.00008363	2.08	0.53	1.536	60	0.796
	2.0	20	40	3.0		30	1.15	0.007	0.00006763	2.16	0.61	1.772	60	0.919
			40	3.0		30	1.22	0.007	0.00006375	2.18	0.64	1.843	60	0.955
	2.0	20	40	3.0	33	30	1.43	0.007	0.00005439	2.23	0.71	2.044	60	1.060
			40	3.0		30	1.65	0.007	0.00004714	2.28	0.77	2.241	60	1.162
			40	3.0		30	2.20	0.007	0.00003535	2.36	0.93	2.685	60	1.392
II	0.5	30	60	3.0	24	22	0.85	0.007	0.0001248	1.53	0.32	0.618	60	0.320
			60	3.0		22	0.93	0.007	0.0001140	1.58	0.35	0.666	60	0.345
			60	3.0		22	1.15	0.007	0.00009223	1.69	0.41	0.790	60	0.410
	1.0	30	60	3.0	24	22	1.18	0.007	0.00008988	1.70	0.42	0.806	60	0.418
			60	3.0		22	1.24	0.007	0.00008553	1.72	0.43	0.838	60	0.434
			60	3.0		22	1.14	0.007	0.00009279	1.68	0.41	0.786	60	0.408
	2.0	30	60	3.0	24	22	1.65	0.007	0.00006428	1.85	0.54	1.041	60	0.540
			60	3.0		22	1.73	0.007	0.00006131	1.87	0.56	1.078	60	0.559
			60	3.0		22	2.15	0.007	0.00004933	1.97	0.65	1.261	60	0.654

Table 3: Ecological Coefficients Describing the Risk Level in the Ground-Soil Settlement Layer

No		Degree of the ground-soil salinity		
		Low	Average	High
1.	Area, ω_{nt}, *ha*	200	200	200
2.	Initial salinity point, So,%	0.34	0/52	1.6
3.	Fenestration, *n,* in fractions	0.44	0.44	0.44
4.	Soil density, T/m^3	1.42	1.42	1.42
5.	Initial mineralization, g/*l*	2	2.7	4.5
6.	Salts residue, *T/ha,* S=100 h· γ· So	23	26	68
7.	Groundwater level (GWL), *h,m;*	2.8	2.8	2.8
8.	Water volume till GWL, W_{GWL}, m^3/ha $W_{GWL}=10^4 \bullet n \bullet h$	12320	12320	12320
9.	Net flushing rate, N_{nt}, m^3/ha	5000	6000	7000
10.	Gross flushing rate, N_{br},m^3/ha	6000	7200	8500
11.	Salts stock in GW, S_{GW}, *kg/ha*	24640	33264	55440
12.	Permissible mineralization in the soil solution $C_{\partial}= \Delta S+S_{GW}/ W_{GWL}+ N_{br}$, *g/l*	2.6	3	5.9
13.	Water inflow from the channels *Q,* m^3/sec	0.2	0.2	0.2
14.	**Ïðîäîëæèòåëüíîñòü ïðîìûâêè**, $t=N_{nt} \bullet \omega_{nt} / 86400 \cdot \eta \bullet Q$, *day*	68	82	95
15.	The share of transit water discharged into the river during the flushing process $V_{``}=N_{nt} \bullet \omega_{nt} / 86400 \bullet Q \bullet t$	0.85	0.85	0.85
16.	Flushing period precipitation –, m^3/ha	380	540	640
17.	Moisture saturation in the settlement layer, $W_{и}$, m^3/ha;	3266	3266	3266
18.	Evaporation in the flushing process, E_o m^3/ha	1000	1200	1500
19.	Volume share of flushing water coming from the CBC: $q_k=(N_{nt}+–- W_i-E_i)/ N_{br}$	0.19	0.29	0.34
20.	Salinity chemistry, chloride - sulphate (ch-s)	x-c	x-c	x-c
21.	Environmental factor Э= 1-exp($-C_{\partial} \bullet V_m \bullet q_k$)	0.34	0.52	0.82
22.	Threat level	Moderately dangerously	Dangerously	Very dangerously

The calculation of groundwater recharge due to the filtering from the channel (Table 2) was carried out taking into account the drain distance from the check center, capacity of the aquifer to water pressure, power of the groundwater flow and evaporation rates to determine the drainage and flushing rates [5].

To adjust the parameters of the technological system of flushing with the groundwater recharge through infiltration, it is necessary to regulate water and physical properties of soils especially in the case of deep tillage and temporary drainage.

The determination of the soils ability to hold water available to plants depends on its certain properties. Any additional amount of water from rainfall or irrigation, the increase of the groundwater level (GWL) greater than this value is redundant and can disrupt the soil hydrological balance. Depending on soil permeability, landscape, lithology and hydrography, the excess water may be infiltrated into the groundwater, turn into the areas water logging, which will affect the natural landscape, environment, environmental and economic performance, as well as soil fertility that is a factor of pollution. The analysis of the calculations in the table form shows the quantitative assessment of the environmental situation of the analyzed objects: the threat level (very dangerous, EC = 0.52-0.82) [11-16].

CONCLUSION

The technology was developed and implemented on the pilot production sites of “Zhaisan” and “Kokozek” of Zhambyl oblast, with strongly saline soils of sulfate-chloride salinity type. On the basis of experimental research in Tasotkul and Talas areas of Zhambyl oblast there was developed water-saving flushing technology in comprehensive reclamation with the use of chemical meliorants (phosphogypsum), in combination with organic fertilizer and deep loosening of soil-ground density layers [10-12,15-16].

The research showed that capillary rise and soil water loss varies at different levels of ground water. Ultimately, there is pollution, waterlogging of the soil root zone in the absence of drainage in the settlement layer. To prevent these processes it is necessary to determine timely the soil moisture content in the soil-ground aeration zone.

The results of the water-saving flushing technology implementation show that it is economically expedient to carry out flushing 5-6 times with a single norm of 800- 1000 м^3/ha on the background of a constant drainage with the use of temporary one spacing in the range of 40-100 m and a depth of 1.2 m. At the same time the total flushing rates were 5000-6000 м^3/ha.

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