Improving water-salt regime in irrigated agriculture

Kanat Anuarbekov, Orakhbay Zubairov and Mukhtarbek Nusipbekov

Kazakh National Agrarian University, st. of Abay, 8, Alma-Ata, 050000, Republic of Kazakhstan

Abstract. This article studies the ameliorative condition of lands in Shieli irrigation massif by analyzing the volume of salts ingression into soil along with irrigation water and salt outcrop from the soil in sewer waters. The paper presents materials with experience of flushing saline on the area of 71.15 hectares, which gave positive results in water-and salt regime of soil.
[Anuarbekov K., Zubairov O., Nusipbekov M. **Improving water-salt regime in irrigated agriculture.** *Life Sci J* 2014;11(5):459-464] (ISSN:1097-8135). http://www.lifesciencesite.com. 65

Keywords: Salinity, experimental plot, agriculture, checks, flushing, drainage.

Introduction

In the Shieli district of Kyzyl-orda region in 2013, the area of irrigated land was 31,118 hectares. Out of that area, the area of irrigated land with utility systems is 25,801 hectares, and the total area of fields is 22,736 hectares. [1]

Weather conditions. The Shieli district is characterized by hot summers and very cold winters. The favorable period for crop planting continues from April to mid-October. The hottest month is July; the coldest months are January and February.

Within the area, except for some years, rainfalls are very rare. Atmospheric precipitation occurs in winter and spring.

According to the data from the Shieli Weather Stations, the amount of precipitation this year was 164.7 mm. The highest temperature was +27℃ and the lowest temperature was 4.80℃; the average temperature being +13.30℃ [2, 3].

The main source of water for irrigation of agricultural crops in the Shieli area is the Syrdarya River. The main part of the river water intake originates in the Tomenaryk town through the trunk channel Novy Shieli. Through this channel, agricultural land in Akmaya, Kodamanov, Begezhanov, Zhuantobe, Bestam and other farms is irrigated. Through the Kamystyayak channel, farms in villages Bidaykol and Jahanev are irrigated.

In the area, the water supply into the channels starts on the third week of April. Water supply to the fields starts in May and continues until August 25.

Hydrogeological and ameliorative conditions of the irrigated lands are a complex system, i.e., they depend on soil salinity, water supplied to crops and the level of ground water. [4, 5]

Through pipes located in irrigated areas, groundwater level and salinity indicator were identified. The ameliorative condition of the irrigated land in farms was considered unsatisfactory only in certain farming lands, due to their lowland and highland location, a change was noticed in soil mechanical composition.

Soil salinity index depends on mineralization of irrigation water and groundwater. In the autumn of this year, a rapid drop of the groundwater level has been observed. This was caused by the fact that the water level of the Syrdarya River was lower, and the groundwater level in irrigated land dropped rapidly.

Methods

Chemical composition of soil and water was determined in the laboratory. I.e., content of (PH), total nitrogen (N), ammonium and nitrate nitrogen, sulphates (SO_4), chlorides (Cl) was determined by the method developed by Y.Y. Lurye and A.I. Rybnikova [2]. However, content of calcium (Ca) and magnesium (Mg) was determined using a complex-metric method, content of potassium (K), sodium (Na) was determined using a photometer, and air chemical humidity (chemical oxygen demand) was determined using the dichromate method.

Soil chemical composition was determined twice a year, in spring and in autumn. Samples of soil at a depth of 60 cm were taken every 10 cm, and further to the depth of 100 cm, each 20 cm in 3 repetitions.

Soil moisture was determined by the drilling and the thermostatic method.

The norm of salt flushing was determined by the equation of V.R. Volobuyev [6]:

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

where: M is the norm of flushing, m3/hectare;

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

S_0 is restricted (limited) value of salt in 1 meter thick layer of soil, %;

α is the amount of water for flushing 1 ton of salts from soil. In terms of Kyzyl-Orda, according to the data from Zh. Baymanov, this figure is equal to $\alpha = 0.50$. [7]

In conditions of the experiment, flushing is performed twice, 2300 m^3 of feed water each. The period between the first and second flushing is 5 days.

The mount of salt collected in the soil is found by multiplying irrigation norms by the amount of salt ingress with water. And the amount of salt withdrawn from the soil is determined by multiplying the volume of sewage water by its salinity.

In our experimental plot with the area of one check of 0.5 hectares, amount of water supplied to the check was 1150 m^3/hectare, i.e., 1150000 liters of water should be supplied. Water-transmitting capability of the channel is 100 l/s.

$$t = \frac{1150000}{100} = \frac{11500\,sec}{60\,sec} = \frac{192\,min}{60\,min} = 3.2\,hours$$

Then on 1 limit-flushing operation we shall spend 3.2 hours. And the entire plot of 71.15 hectares is washed out for 19, or 454.4 hours/24 days. This is one-time flushing. Water is released again every 5 days. The entire flushing process takes 38 days.

Main part

The experiments were made on 71.15 hectares of Bidaykol agricultural land plots in Shieli region (Fig. 1). We called these plots B-71-8, i.e., here B stands for Bidaykol, 71 is the area of the irrigated plot and 8 stands for the number of the well in the irrigated plot. Crops in locations where we carried out the experiments are located in the southwestern part of the Bidaykol irrigated cultivation farm. Well No. 8 is the closest to it. 49 hectares of alfalfa and 22 hectares of silage maize were planted on our experimental arable farm field. [1, 2]

About 24 sewage pipes are installed in the farm. Since they were installed in 1980, at the moment only 18 of them are operating. Using the data obtained from these pipes and our own data from water studies, we determined land salinity indicators.

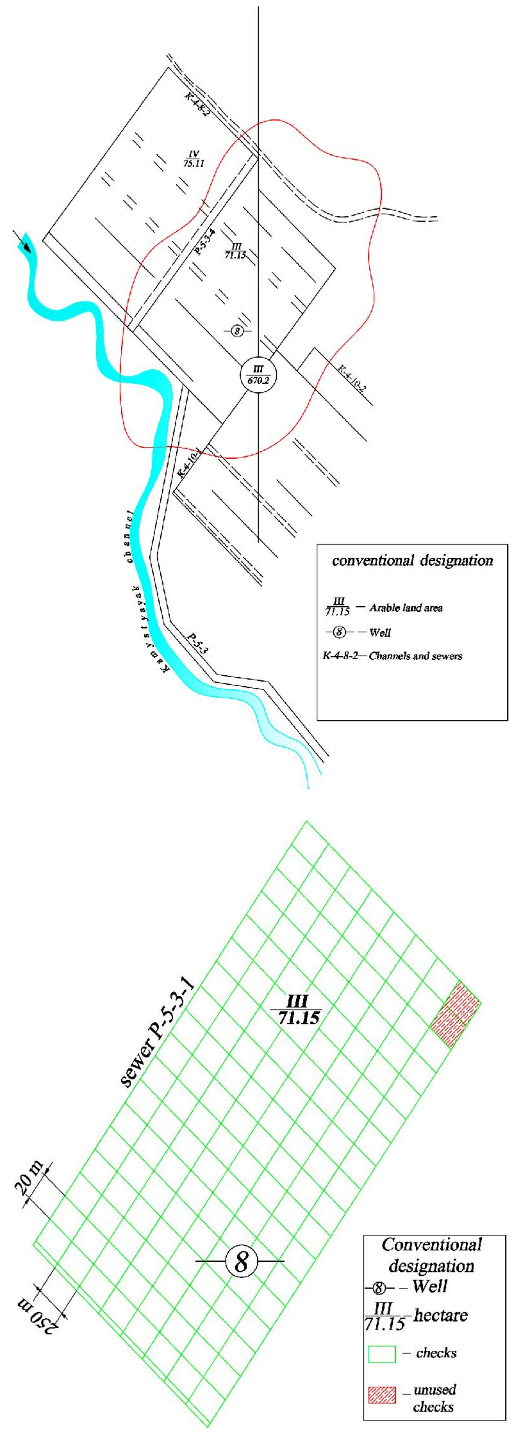

Fig. 1. Hydrogeological and ameliorative conditions of experimental plot B-71-8 (the Bidaykol irrigated farm field)

While in March (2013) the groundwater level was 2.64 m, its salinity was 3.52 g/l, in June, the groundwater level was 1.40 m, its salinity was in the range of 2.55 g/l, and in October, the groundwater level was 2.38 m, its salinity was 3.00 g/l.

In irrigated agriculture, cereal and forage crops are mainly cultivated. Here, the main crop, rice, as well as grain maize, early crops, several kinds of alfalfa, etc., are cultivated. (Fig. 2)

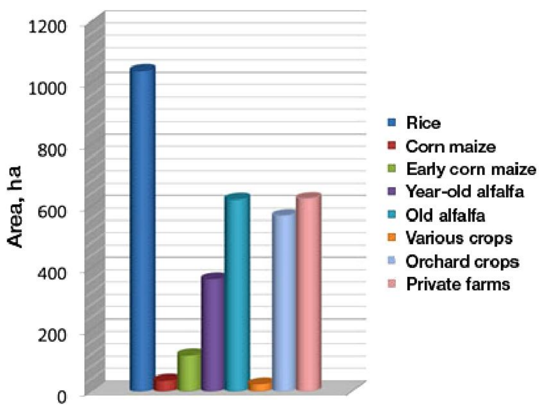

Fig. 2 Main crops cultivated at Bidaykol agricultural farms

Table 1. Data on experimental land plot B-71-8 in terms of water intake, water supply to crops during the vegetation period (2013) and precipitation in the area according to the data from the Shieli Weather Station (2012-2013) [1, 2, 3]

Indicators	Experimental plot B-71-8
Water intake (planned), mln.m3	1.11
Water supply to fields (planed), mln.m3	1.01
Water intake (actual), mln.m3	0.90
Water supply to fields (actual), mln.m3	0.68
Amount of water sent to the drainage, mln.m3	0.18
Performance	0.82
Precipitation (2013, average per year), mm	164.7

Also, the discharged water is driven via drainage P-5-3-1. Fig. 3 shows the total amount of salts in the soil plot used for the experiments.

In order to improve the salt regime for years 2011-2013, soil flushing was undertaken for two consecutive years. At the beginning, in the plot of 71.15 hectares, the initial amount of salts in the soil was 1.757% by weight of dry soil. Flushing was made jointly with Bidaykol economic institution.

Soil was flushed, and salt-and-water regimes were studied on land plot of 71.15 hectares.

The aim is the establishing of water-salt regimes of cultivated land under optimal conditions.

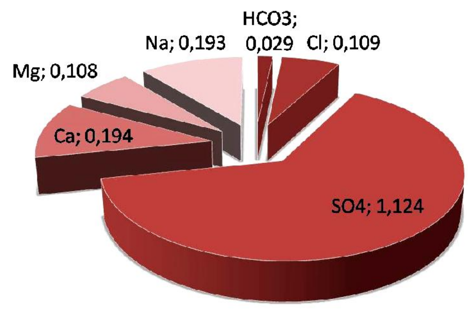

Fig. 3. Indicators of salts in the soil of experimental plot B-71-8

To achieve this goal, the following works were performed:

definition (by laboratory methods) of soil chemical composition before the experiment;

definition of the amount of water taken for irrigation of crops, and its salinity;

definition of the amount of drainage water and its salinity;

crop yield from irrigated fields;

chemical composition of soil and water was defined in a specially equipped laboratory of the regional committee for Environment protection and biological resources. [8,9,10]

On 71.15 hectares of agricultural land, checks were prepared in advance. The area of each check was 250*20 m^2. The total number of checks was 144, including two checks that were considered worthless lands.

Before flushing with this amount of water, the following work was performed:

grading the land plot;

preparation of a protective belts at the height of 0.25 m;

preparation of trapezoidal Thompson drainage system in order to normalize the checks' water supplying channel system;

definition of common indicators of salt in one meter thick layer of soil before flushing, in March, 2012;

in accordance with results of laboratory analysis, the overall content of salts in the one meter thick layer of soil amounted to 1.757% by weight of dry soil.

General flushing results are presented in Table 2.

Fig. 4 shows the table image as a histogram.

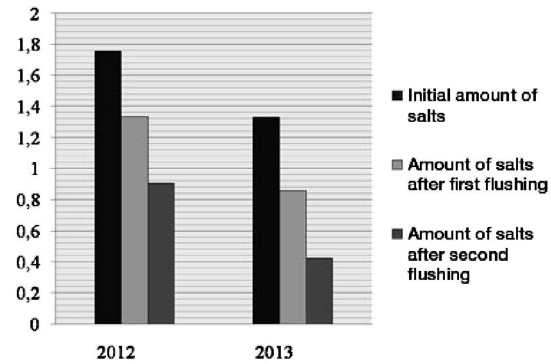

Fig. 4. Dynamics of plot flushing norms

As it is seen from Table 2 and Fig. 4, the initial amount of salts in the experimental plot B-71-8 of the Bidaykol agricultural farm where the study was performed was 1.757% by weight of dry soil. With these indicators, it was hard to get a good harvest from this area. The salt content indicator beneficial for plants should be within the range 0.3 to 0.5%. Within 2 years, thanks to normal flushing, salts content reduced from 1.757% to 0.422%. Yield of alfalfa and silage maize grew. According to the data for the autumn of 2011, from the 2600 hectares of alfalfa in the Shieli region (while the total area of the region is 24,081 ha), 10 kg/hectare yield was obtained. In the calculation of this index, the 49 hectares of alfalfa of our experimental plot amounted to the yield of 0.19 t/hectare, and for silage maize, the area of 172 hectares amounted to the harvest of 65.8 c/hectare in calculating this indicator. 22 hectares of silage maize in our experimental plot amounted to the yield of 8.41 t/hectare.

These figures changed after flushing several times. While in year 2012 from our experimental plot with 49 hectares of alfalfa (at that time the total planting acreage was 31118 ha) we obtained the yield of 0.28 t/hectare, and from 22 hectares of silage maize we obtained the harvest of 14.36 c/hectare, in 2013 the yield amounted accordingly to 0.33 t/hectare and 17.75 t/hectare.

These data made it possible for us to calculate the water-and-salt regime of the considered irrigated plot. [11.12.13]

Conclusion

Elements of the water balance**:**

2. The volume of water supplied to the experimental plot B-71-8 was 0.67 m³/sec;
3. Expenditures for water absorption from the main channels were calculated in the amount of water received.

Table 2. Indicators of flushing norms for 2 years at experimental plot B-71-8 of the Bidaykol agricultural farm, %

No.	Indicators	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	Amount of salts
1	2	3	4	5	6	7	8	9	10
				Year 2012					
1	Initial amount of salts in soil (data obtained in March 2012)	0.000	0.029 0.48	0.109 3.08	1.124 23.42	0.194 9.70	0.108 8.90	0.193 8.38	1.757
2	Amount of salts after the first flushing norm (flushing started on March 13 and ended on March 31)	0.000	0.014 0.23	0.083 2.37	0.831 17.31	0.159 7.95	0.082 6.78	0.163 7.09	1.332
3	Amount of salts after the second flushing norm (flushing started on April 5 and ended on April 24)	0.000	0.008 0.13	0.059 1.68	0.526 10.96	0.124 6.20	0.058 4.79	0.131 5.69	0.906
				Year 2013					
1	Initial amount of salts in soil (data obtained in March 2013)	0.000	0.015 0.25	0.086 2.46	0.822 17.12	0.152 7.60	0.084 6.94	0.169 7.35	1.328
2	Amount of salts after the first flushing norm (flushing started on March 15 and ended on April 3)	0.000	0.007 0.11	0.052 1.48	0.513 10.69	0.105 5.25	0.053 4.38	0.128 5.56	0.858
3	Amount of salts after the second flushing norm (flushing started on April 8 and ended on April 27)	0.000	0.003 0.05	0.027 0.77	0.206 4.29	0.063 3.15	0.022 1.82	0.101 4.39	0.422
	Difference (+/-)	0.000	0.026	0.082	0.918	0.131	0.086	0.092	1.335

$F_k =$ amount of water (water intake) x efficiency (1-efficiency channels) m³/sec;

$$F_k = 0.85x(1 \quad 0.82) = 0.15 \text{ mln. m}^3$$

4. According to Soyuzgiproris data, incoming and outgoing ground water have been calculated as equal.
5. According to weather station data, for years 2012-2013 the amount of atmospheric moisture amounted to 164.7 mm.[²]
6.

$$164.7\text{mm}\ x10x71.15\ ha = \frac{117184.05}{1000000} = 0.12$$

m³/sec

7. According to the data of the Hydrogeology institute, the amount $\sum Z$ of evaporation is equal to known indicator of evaporation of plants and water movement

F_{total} - total area of 71.15 hectares;

F_{al} - total area of alfalfa 49 ha;

F_{sm} - total area of silage maize of 22 hectares;

F_{rfl} - area of rain-fed lands of 0.15 ha;

Z_{al} - evaporation of water from the surface of lands occupied by 12 hectares of alfalfa;

Z_{sm} - evaporation of water from the 0.80 hectares of silage maize;

Z_{rfl} - evaporation of water from rain-fed lands of 0.08 ha; (Table 4)

$$\sum Z = \frac{49x12 + 22x0.80 + 0.15x0.08}{71.15} = \frac{605.612}{71.15} = 0.085$$

thousand m³/hectare

Table 3. Water balance

Elements of water balance	1 hectare thousand m³	Total mln. m³
1	2	3
Incoming		
Supplied water		0.67
Atmospheric moisture		0.12
Water absorbed by MK		0.15
Total		0.94
Consumption		
Amount of evaporation	0.085	0.25
Drainage water		0.18
Vertical absorption		0.30
Total		0.73
Balance		**0.21**

8. Drainage-and-drainage water amounted to 0.18 mln. m³
9. In rice fields, vertical water absorption according to the Soyuzgiproris institute is 0.30 thousand m³/hectare.

Raising the groundwater on all irrigated, rain-fed cultivated fields in the water balance:

$$dH = \frac{0.21}{71.15x0.17} = 0.02\,\text{m}$$

Elements of salt balance:

1) Changes of soil salinity is determined by the following formula:

$$\sum Z = (S_{суар} + S_{сі} + S_{атм}) - (S_{кол} + S_{нім})$$

$S_{орош}$ *is the amount of salts coming with the waters of the channel 0.67 x1.30 = 0.87 thousand tons;*

$S_{впит}$ *is the amount of salts coming with absorbed water 0.15 x 1.30 = 0.19 thousand tons;*

$S_{атм}$ *is the amount of salts coming with atmospheric moisture 0.12 x 0.85 = 0.10 thousand tons;*

$S_{кол}$ *is the amount of salts coming through the drainage waters 0.18 x 3.88 = 0.70 thousand tons;*

$S_{урож}$ *is the amount of salts brought out with crop yield of 0.41 thousand tons* (Table 4)

Table 4. Salt balance

Elements of salt balance	Amount of salts. thousand tons
1	2
Incoming	
With irrigation water	0.87
With assimilated water	0.19
With atmospheric moisture	0.10
Total	1.16
Consumption	
With drainage water	0.70
With yield	0.41
Total	1.11
Balance	**0.05**

According to these two tables, the amount of water coming to the experimental plot was 0.94 mln. m³, and the water flow was 0.73 mln. m³. The difference of 0.21 mln. m³ of water is lost. In case of 1.16 thousand tons of salt coming to soil, and 1.11 thousand tons of salt outgoing, the difference of 0.05 thousand tons of salt remains in the soil.

Conclusion

So, at present, in order to further improve the water-and-salt regime of soil, it should be flushed every year. Flushing is the most effective in autumn and early spring. During these seasons, water level in the Syrdarya River is higher, and the amount of salt is lower.

Corresponding Author:
Dr. Anuarbekov Kanat
Kazakh National Agrarian University
st. of Abay, 8, Alma-Ata, 050000, Republic of Kazakhstan

References

1. Final Report for Year 2013 on the Shieliysk Region, 2014. RMM Kyzylorda Hydrogeological and Ameliorative Expedition, Kyzylorda.
2. Final Report for Year 2013 on the Shieliysk Region, 2014. RMM Shieli Weather Station, Shieli.
3. Materials on the Chemical Composition of the Syrdarya River Water in 2010-2013, 2014. Kyzylorda Regional Administration for Ecology and Bioresources, Kyzylorda.
4. Shomantaev, A.A., 2001. Hydro-chemical regime of water courses and agricultural use of sewage and drainage water in the lower reach of the SyrDarya River. Kyzylorda:, pp: 182-199.

5. Verma, A.K., S.K. Gupta and R.K. Isaac, 2012. Use of saline water for irrigation in monsoon climate and deep water table regions: Simulation modeling with SWAP. Agricultural Water Management, 115: 186-193.
6. Volobuev, V.R., 1975. Calculation of flushing saline soils. Moscow: Kolos, pp: 156-178.
7. Baimanov, J.N., 1997. Use of drainage for flushing saline soils. In the Proceedings of the International Scientific Conference "Problems of Ecology in Agribusiness and Environmental Protection", National Agricultural Institute, Almaty, Kazakhstan, pp.40-42.
8. Norum, D.J et al, 1979. Acolication of System Optimal Depth Concept-Journal of the irrigation and Drainage Division. In the Proceedings of the ASAE, pp: 48-57.
9. Kutch, H. and H. Schuh, 1980. Versuschder mathematischen Darstellungg der Wasserbedafsh-ocffisient for bewasserte. Kulturen-Zeitschut for Bewasserung swirtshaft, pp: 183-191.
10. Elson, A., 1973. In-house manure drying. Poultry Industry, 37: 14-15.
11. Rong-jiang Yao. Jing-song Yang. Tong-juan Zhang. Li-zhou Hong. Mao-wen Wang. Shi-peng Yu. Xiang-ping Wang, 2014. Studies on soil water and salt balances and scenarios simulation using SaltMod in a coastal reclaimed farming area of eastern China. Agricultural Water Management, 131: 115-123.
12. LeBlanc, D., 2010. Molten salt reactors: A new beginning for an old idea. Nuclear Engineering and Design, Vol.240, 6: 1644-1656.
13. Zörb, Ch., Ch.-M. Geilfus, K.H. Mühling and J. Ludwig-Müller, 2013. The influence of salt stress on ABA and auxin concentrations in two maize cultivars differing in salt resistance. Journal of Plant Physiology, Vol. 170, 2: 220-224.

4/24/2014