Ecological aspects of the state of natural and technical systems in the zone of irrigated agriculture effect

S.A. Manzhina[*], *T.I.* Drovovozova, and *A.A.* Kirilenko

Russian Scientific Research Institute of Land Improvement Problems, Novocherkassk, Russian Federation

Abstract. The purpose of the study is to identify the ecological aspects of the state of natural and technical systems in the zone of irrigated agriculture effect on the example of the hydrographic network of the left bank of the Lower Don. The Semikarakorsky district of the Rostov region was chosen as the object of the study. The subject of the study was the water quality in natural-technical systems – receivers of collector-drainage runoff from reclaimed lands, collector-drainage network, irrigation channels, as well as hydrochemical indicators of groundwater with a depth of no more than 5 m, soils from irrigated fields and fields with natural irrigation (boghara). The analysis of the results showed the widespread effect of groundwater on the formation of the drainage runoff and natural water composition, the accumulation of sodium ions and sulfates in soils, which is due to the rise of the capillary fringe due to the rise of the groundwater level. In general, the chemical composition of drainage water corresponds to the geochemical background of the territory and is a consequence of their natural desalinisation.

1 Introduction

The best crop yields in areas with natural irrigation shortage are achieved against the background of artificial irrigation during their growing season. To implement irrigation measures, water is transported through closed and open reclamation systems. If necessary, they are equipped with a collector-drainage network through which excess water after irrigation is diverted to natural water bodies or to other territories. It is known that under the effect of irrigation, as a result of changes in water distribution, the water balance of natural and technical ecosystems changes, acceleration of leaching of water-soluble compounds from soils and activation of their removal into water bodies from the catchment area is observed [1-5]. Changing the balance of substances on irrigated lands and adjacent territories involves conducting agroecological monitoring and eco-oriented economic activity, considering the speed and direction of accelerated recycling of substances.

The Southern Federal District (SFD) of the Russian Federation has favorable temperature and soil conditions for growing a wide range of crops. Nevertheless, part of the

[*] Corresponding author: manz.svetlana@yandex.ru

district's territories experience a significant shortage of precipitation during the vegetation period of agricultural crops, which is a limiting factor for agricultural production.

The Semikarakorsky district of the Rostov region, which is one of the subjects of the Southern Federal District, was chosen as the object of the study. The territory of the Semikarakorsky district, in accordance with the adopted zoning, belongs to the steppe zone and is included in the "arid subzone" [5, 6]. During the Soviet period, the agriculture of the region developed against the background of the construction and arrangement of a complex of irrigation systems, which marked the emergence of irrigated agriculture. The district became part of the central irrigated zone of the region. The irrigated lands of Semikarakorsky district are provided with water through the Lower Don irrigation system with water intake from the Don Main Channel (DMC), where water comes from the Tsimlyansk reservoir [7].

In recent decades, there has been a deterioration in the hydrochemical state of natural-technical systems and natural water bodies of the Lower Don basin, due, among other things, to intensive agricultural activity.

In connection with the above, the purpose of the study is to identify the ecological aspects of the state of natural and technical systems in the zone of irrigated agriculture effect on the example of the hydrographic network of the left bank of the Lower Don.

2 Materials and methods

The subject of the study was the water quality in natural-technical systems – receivers of collector-drainage runoff from reclaimed lands, collector-drainage network, irrigation channels, as well as hydrochemical indicators of groundwater with a depth of no more than 5 m, soils from irrigated fields and fields with natural irrigation (boghara).

The soil composition of the territory under consideration is determined by the established processes of formation: ordinary chernozems predominate [5]. In accordance with the geomorphological zoning of the Rostov region, Semikarakorsky district is located within the alluvial-accumulative plain of the Lower Don. The parent rocks are mainly represented by carbonate loessial clays and loams with a thickness of 6 to 50 m of fluvio-glacial, alluvial, and alluvial-deluvial origin [8].

Groundwater in the study area is of the sulfate-bicarbonate type in anionic composition with a predominance of sodium, calcium, and magnesium cations, which plays a decisive role in the formation of the chemical composition of surface waters of small water bodies. According to the dynamics of intra-annual fluctuations of groundwater levels, the maximum is observed in the spring period (April–May) and the minimum - in the autumn (September-October) [9]. The largest number of polluting components is observed in the area of the city of Semikarakorsk and is characterized by an excess content of nitrates, iron, silicon, petroleum products [9].

The hydrochemistry of groundwater based on the results of regime observations for the period 2009-2013 is shown in Table 1.

Table 1. Ionic composition of groundwater in Semikarakorsky district [9]

Mineralization	Ionic composition, mg/dm^3							Hardness, mg-eq./dm^3	pH	CH_4, µl/l
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	SO_4^{2-}	Cl^-			
1,11–3,35	32–432	46–325	108–613	<1–32	393–1793	213–1136	97–814	14,6–27,0	6,88–8,27	<0,1–106,0

Water use facilities

The natural and technical systems of the Lower Don basin are divided into three water management areas. The water management site 05.01.03.010 (Figure 1) includes the river Erik Besheny and the K-3 channel, from which drainage water is discharged through outlet No. 1, the Salyonaya River, into which discharge from the collector channel LS-2 is carried out through outlet No. 2, the natural limit of the Kolodezka River into which water is discharged from the discharge channel MKL-7 through outlet No 3.

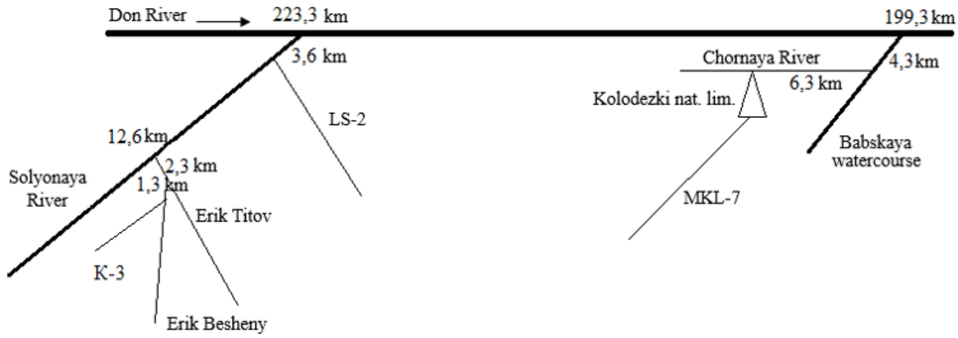

Fig. 1. Scheme of receipt of collector and drainage waters of the Semikarakorsk branch of the FSBI "Directorate "Rostovmeliovodkhoz" in water bodies on the water management site 05.01.03.010

The water management section 05.01.05.009 includes the Central Discharge Channel, which flows through the Semikarakorsky backwater into the Don River 174 km from the entry through outlet No. 4 and the Kostylevsky Pond, into which water from the BG-MS-4 collector is discharged through outlet No. 5 (Figure 2).

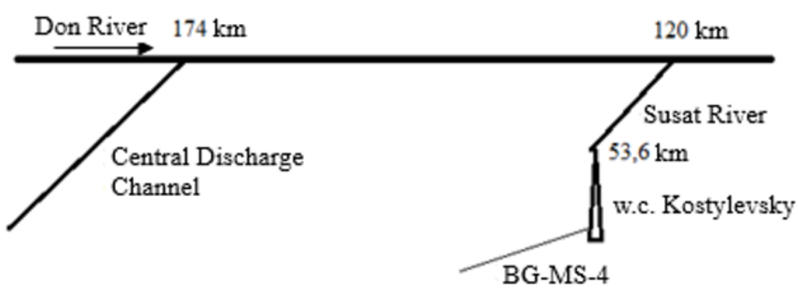

Fig. 2. Scheme of receipt of collector and drainage waters of the Semikarakorsk branch of the FSBI "Directorate "Rostovmeliovodkhoz" in water bodies on the water management site 05.01.03.009

The water management section 05.01.05.001 includes Lake Kalmytskoye, into which is being discharged through the outlet No. 6 from the BG-MS-1 channel and from the KSB channel into the Sal River are discharged through the outlet No. 7. Sampling in the facilities of the water management site 05.01.05.001 was not carried out due to the lack of drainage water.

The observation period under consideration is 2009-2020.

Physicochemical methods of qualitative and quantitative analysis according to approved methods, evaluation and statistical data processing were used as research methods.

3 Results and discussion

Summary data on the hydrochemical composition of water samples of the studied objects are presented in Table 2.

The analysis of hydrochemical parameters in the studied samples of water from reservoirs showed the widespread effect of groundwater on the formation of drainage water composition, due to the shortage of surface water drainage.

The results of the analysis of soil samples are shown in Table 3.

Table 3. Chemical indicators of soils in the area of reclamation systems of bogharic and irrigated lands (horizon 0-20 cm) at the beginning and end of the irrigation period.

Indicators	Measuring units	Soil samples around channels							
		K-3		LS-2		MKL-7		CS (southern)	
		boghara	irrigated	boghara	irrigated	boghara	irrigated	boghara	irrigated
Sampling date 14.05.2019									
pH_{water}	Unit pH	7.8	7.9	7.95	7.7	7.7	7.85	7.7	7.6
Cl^-	mg/100 g of soil	13.26	13.42	11.34	14.38	15.02	17.57	11.18	12.78
SO_4^{2-}	mg/100 g of soil	2.93	2.93	4.37	4.8	4.56	4.37	4.18	2.49
HCO_3^-	mg/100 g of soil	59.48	59.48	56.10	57.34	57.34	54.9	61.0	56.4
Ca^{2+}	mg/100 g of soil	16.0	15.0	17.0	17.0	17.0	15.5	17.0	14.0
Mg^{2+}	mg/100 g of soil	1.53	2.14	3.66	2.75	3.05	3.97	3.66	2.14
$Na^+_{calc.}$	mg/100 g of soil	10.6	10.7	4.25	6.75	6.58	7.38	4.13	10.25
Sampling date 06.09.2019									
pH_{water}	Unit pH	6.47	6.47	7.2	7.2	7.35	7.35	7.2	7.2
Cl^-	mg/100 g of soil	16.51	10.75	14.13	16.79	11.18	21.37	12.07	13.99
SO_4^{2-}	mg/100 g of soil	14.88	9.41	8.59	10.57	1.725	12.86	8.59	5.57
HCO_3^-	mg/100 g of soil	36.6	71.67	48.8	42.7	67.1	64.05	57.95	50.325
Ca^{2+}	mg/100 g of soil	9.12	13.44	17.28	21.12	17.76	24.0	17.76	8.64
Mg^{2+}	mg/100 g of soil	0.86	1.296	0.86	2.02	2.02	3.17	0.86	2.59
$Na^+_{calc.}$	mg/100 g of soil	19.41	20.56	10.14	12.37	9.08	10.49	11.71	15.80

Table 2. Summary table of average values according to water sampling data from various sources.

Sampling location	pH, unit pH	BOD, mgO_2/dm^3	Total hardness, $mmol/dm^3$	Ingredients, mg/dm^3																
				suspended matters	dry residue	Cl^-	SO_4^{2-}	HCO_3	Ca^{2+}	Mg^{2+}	Na^+	NH_4^+	NO_2^-	NO_3^-	PO_4^{3-2}	Fe_{tot}	Cu^{2+}	Anionic surfactants	Zn^{2+}	NFPR
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Regulatory indicators																				
$MPC_{c.f.}$[3]	6.0-9.0	3.0	7-10	10	-	300	100	-	180	40	120	0.5	0.08	40	0.2	0.1	0.001	0.1	0.01	0.05
$MPC_{h.p.}$[4]	6.5-8.5	3.0	7-10	-	-	350	500	1000	-	50	200	1,5-2,0	3.3	45	3.5	0.3	1.0	0.2	1.0	0.3
2. Irrigation water																				
DMC main structure[5]	7.6	1,97	4.80	5.30	354.0	85.10	67.20	170.9	52.10	26.80	n/d	<0.05	0.076	0.20	0.29	0.10	<0.002	<0.010	<0.005	0.022
BMC main structure	7.7	1,97	5.00	5.30	412.0	92.20	76.80	170.9	56.10	26.80	n/d	<0.05	0.077	0.15	0.27	0.12	<0.002	<0.010	<0.005	0.020
DNMC main structure	8.15	n/d	5.40	4.80	649.0	80.0	159.0	223.0	64.90	26.30	95.8	n/d	n/d	n/d	n/d	0.10	<0.0006	n/d	0.0007	not det.
NDMC (end part)	8.10	n/d	5.30	4.60	627.0	80.0	142.0	226.0	62.10	26.80	90.1	n/d	n/d	n/d	n/d	0.10	0.0012	n/d	0.0013	not det.
3. Ground water																				
Well (depth of 5 m)	7.80	n/d	24.40	1.80	2471	140.00	1027.0	638.00	214.00	167.00	285.0	n/d	n/d	n/d	n/d	0.22	0.001	n/d	0.008	n/d
4. Waste (drainage) water and background concentrations in the drainage water receiver[6]																				
Eril Besheny (background)[7]	7.60	3.34	n/d	6.43	1651	390.55	426.10	n/d	127.90	50.14	328.53	n/d	n/d	n/d	0.09	0.147	n/d	n/d	n/d	n/d
Outlet No. – K-3 channel	7.67	2.34	13.96	5.59	1993.2	404.28	754.4	n/d	155.38	74.56	390.40	n/d	n/d	n/d	0.084	0.116	n/d	n/d	n/d	n/d
Solyonaya River (background)	7.98	2.66	n/d	5.93	1177.0	203.69	372.72	n/d	99.20	40.91	219.43	n/d	n/d	n/d	0.072	0.111	n/d	n/d	n/d	n/d
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Outlet No. 2 – LS-2 channel	7.78	2.77	12.41	5.60	1539.4	203.64	649.00	n/d	142.04	64.22	256.76	n/d	n/d	n/d	0.115	0.096	n/d	n/d	n/d	n/d
Kolodezka	7.85	7.51	n/d	7.01	1595	355.25	443.95	n/d	111.64	45.95	387.28	n/d	n/d	n/d	0.051	0.177	n/d	n/d	n/d	n/d

[2] In clause 4, the phosphorus of phosphates was determined.
[3] On approval of water quality standards for water bodies of fishery significance, including standards for maximum permissible concentrations of harmful substances in the waters of water bodies of fishery significance: Order of the Ministry of Agriculture of the Russian Federation No. 552 dated December 13, 2016 (as amended on March 10, 2020).
[4] SanPiN 1.2.3685-21 Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans.
[5] The data were provided by the ecoanalytic laboratory of the Rostov Hydrogeological and Meliorative Party - branch of the FSBI "Directorate "Rostovmeliovodkhoz".
[6] The average indicators for the observation period over 5 years are presented. The initial data for the calculation are taken from the protocols of the ecoanalytic laboratory of the Rostov Hydrogeological and Reclamation Party - a branch of the FSBI "Directorate "Rostovmeliovodkhoz".
[7] Sampling location for background concentrations 500 m above wastewater discharge (average annual value)

natural limit (background)																				
Outlet No. 3 – MKL-7 channel,	7.75	2.59	10.33	5.55	1222.5	151.50	522.75	n/d	155.90	46.65	224.75	n/d	n/d	n/d	0.087	0.138	n/d	n/d	n/d	n/d
Don River (background)	8.04	n/d	6.16	5.41	592.16	100.84	193.34	n/d	69.00	28.70	97.22	n/d	n/d	n/d	0.090	0.088	n/d	n/d	n/d	n/d
Central discharge, outlet No. 4	7.80	n/d	10.01	5.84	1291.5	207.00	520.25	n/d	153.96	63.52	305.24	n/d	n/d	n/d	0.111	0.105	n/d	n/d	n/d	n/d
Kostylevsky pond (background)	7.87	2.56	n/d	5.60	928.70	89.18	396.23	n/d	90.41	41.11	139.01	n/d	n/d	n/d	0.024	0.095	n/d	n/d	n/d	n/d
Outlet No. 5 – BG-MS-4 channel,	7.89	2.57	8.09	5.29	860.00	87.05	406.25	n/d	87.53	44.23	143.50	n/d	n/d	n/d	0.036	0.082	n/d	n/d	n/d	n/d

The analysis of soil indicators shows an increase in sodium ions, sulfates in the boghara and against the background of irrigation at the end of the irrigation period, which, in our opinion, may be due to the rise of the capillary fringe in connection with the groundwater level rise.

4 Conclusions

The results of the analysis of laboratory studies, with a certain degree of probability, allows to attribute signs of contamination of drainage water to possible natural phenomena. In general, the chemical composition of drainage water corresponds to the geochemical background of the territory and is a consequence of their natural desalinisation.

References

1. A.V. Salmoral G. Carbó, E. Zegarra, J.W. Knox, D. Rey, Journal of Cleaner Production **276 (**2020) doi:10.1016/j. jclepro.123544.
2. G. Jie Ch. Yanyan, Q. Hui, W. Haike, R. Wenhao, Qu. Wengang, Journal of Hydrology **606,** 127437 (2020) doi:10.1016/j.jhydrol.2022.127437.
3. L. Zhongpei, F. Shaoyi, Zh. Dongqing, H. Yuping, C. Runxiang, Applied Water Science **13**(1) (2022) doi:10.1007/s13201-022-01808-y.
4. V.G. Mamontov, P.Yu. Panova, *Irrigated soils*, Russian State Agrarian University, 168 (2017) (in Russian).
5. Ministry of Agriculture and Food of the Rostov Region. 2012. Zonal farming systems of the Rostov region (for the period 2013-2020). URL: http://don-agro.ru/FILES/2020/ZONSYSZEM/Sistema_zemled_do_2020_1.docx (in Russian).
6. Z.M. Ruseeva,and eds. *Agro-climatic resources of the Rostov region*, Hydrometeoizdat, 250 (1972) (in Russian).
7. V.N. Shchedrin, A.V. Kolganov, S.M. Vasiliev, A.A. Churaev, *Irrigation systems of Russia: from generation to generation*. Monograph. in 2 p. 590 (2013) (in Russian).
8. O.S. Bezuglova, M.M. Khyrkhyrova, *Soils of the Rostov region*, Southern Federal University Press. 352 (2011) (in Russian).
9. A.M. Nikanorov, O.B. Burtsev, D.N. Garkusha, E.A. Zubkov, Bulletin of the Southern Scientific Center, **3** 66-80 (2015) (in Russian)