Environmental Improvement of Saline and Alkali Soils in the Kamyslovskaya Valley and Revival of Natural Grassland Efficiency

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Abstract. Agricultural use of saline soils is possible only through implementing reclamation measures on their desalinization. The removal of salt from soils is a cost-demanding and time-consuming process. Expenses related to the treatment of saline soils are connected with a desalinization method and include costs of water supply to a saline area and its drainage. A reasonable project cost, as well as efficient water consumption depends on the use of natural environment conditions. The reported paper presents the assessment of water resources in the drainage area of the valley valley, it is focused on the restoration of water bodies in the Kamyslovskaya log, stabilization of their balance, and environmental improvement; the study suggests economic perspectives of saline and alkali soils. The latter is essential to revive the efficiency of natural grasslands in the valley and its use as a disposal of production and household waste water from surrounding rural settlements.

1. Introduction

Geographically, the Kamyslovskaya log stretches over the territory of two states (the Republic of Kazakhstan and Russia); it crosses the north-east of North Kazakhstan Region in Aiyrtau District, Esil District, Akkayin District, and Magzhan Zhumabaev District and passes into Omsk Region, extending over Isilkulsky District, Moskalensky District, Maryanovsky District, and Omsk District (Figure 1). A territory represents dry lowland with numerous lakes in the valley of the Kamyslovskaya log. A total length of the valley from Bolshoy Tarangul Lake is around 380 km, its width ranges 1.5 to 20 km, and the valley cut into the present day topography is up to 15…17 m.

The surface of the valley is a wavy and poorly dissected lowland plain with numerous shallow holes filled with water – lakes [1]. The valley slopes gently to the north-east like the inclination of underlying rocks that used to be a bank of a fresh-water basin in the Tertiary.

Highest areas are located in the south-west of the valley along the boundary with Akmola Region, where the river Kamysaky has its source at elevations of 200 m and higher. Further north-east, absolute heights decrease to 112 m near Bulaevo, North-Kazakhstan and to 100 m near the urban-type settlement of Maryanovka, Omsk Region.
To date, the economic use of lands in the Kamyshlovsky log is concentrated on its terraces and slopes and comprises individually used farmland for grain and feed crops or natural pastures grazed by domesticated livestock. The efficiency of agriculturally used lands on these areas is not similar. For instance, arable lands of high terraces differ from zones of the watershed and generally depend on moisture conditions of the areas. Along the Kamyshlovsky log there is a strip of saline meadow soils, solod soils, and meadow alkaline soils. The productivity of agricultural fields on terraces creating a gentler slope is lower. It is related to the salinization of soils, which becomes more severe close to the river plain, at a height of 2…3 m from the water edge of lakes they are so poorly productive – even in years with high rainfall amounts a maximum of 3-4 centner/ha (if recalculated to hay) – that they are used for cattle grazing. As for the development of plant communities they have a low value (a content of uneatable species is up to 60%). The reason is salty soils; their percentage is as high as 0.6 to 1.3% in a 0…50 cm layer on sides. Besides it, vast areas on the valley bottom are confined to almost saline and alkaline soils. Typical alkali soils are found around salt lakes.

The efficient land use on this territory is possible provided that desalination actions of saline and alkaline soils are taken; in this case we may increase the productivity of natural grasslands on a total area of above 25 thousand hectares and produce hay of a high quality (15-20 centner/ha). The most optimal measure to reduce a mineralization level of soils is supposed to be the restoration of water bodies aimed at the stabilization of their water-salt balances. Undoubtedly, it will have a positive effect on the efficiency revival of natural meadows in the valley.

2. Hydrographic and hydrologic features of the Kamyshlovsky log

In hydrology, there are mostly bodies with standing water in the valley; a water system represents a chain of lakes with varying sizes and depths, as well as degrees of mineralization. Most lakes in the river basin are without outflow except for the river mouth region with the river Kamyshlovka, which enters the river Irtysh on the left bank at a distance of 1822 km from the river mouth. Water bodies of the rest part have mainly no outlets, only in high-water years some of them may be filled with melt water in spring and turn into running water habitats.

Areas of lake surfaces vary 0.1 to 40 km² (Lake Bolshoy Tarangul). A lot of lakes have low and gently sloping shores, and vast areas get overflooded under a high water level rise, some of them get connected with neighboring water bodies at a distance of several kilometers. As a spring flood is over, water levels of lakes fall because of evaporation, many of lakes dry out. Catchment areas of many lakes...
are small – several tens of square kilometers, and the biggest part of their surfaces (50-60%) were ploughed up. Watersheds are not distinct, therefore, poorly recognizable on topographic maps.

Lakes in the valley are mainly salt lakes with a significant area varying 1300 m² to 4200 m² and a depth of 0.5…1.0 m. A value of total mineralization is in a range 93 to 15 g/l according to the outcomes of survey expeditions carried out by employees of Omsk State Agrarian University in different years. It is related to wide-range water level fluctuations in lakes; in particular, in shallow ones with a large surface area.

Besides salt lakes there are also small but deep (to 2…4 m) fresh-water lakes: Zheltoy, Pokrovka, Presnoye, Pitnoye, Zhelandy, Balykty, etc. A total mineralization level in these lakes varies 0.36 to 3.03 mg/l of chloride and sodium composition with a high concentration of Ca and HCO₃. It relates to the fact that these lakes are deeply cut into the topography and fed by surface streams and subsurface water.

A pattern of fresh-water and salt lakes on the territory is irregular; sometimes they are located close to each other. Fresh-water lakes, in contrast to salt-water lakes, are weeded by marginal aquatic plants, e.g. Phragmites.

For the water balance of a majority of lakes on the territory of interest a lacking outlet is typical, except for infrequent high-water years. The most significant water flowing out was recorded in 1865, when water reached the station of Polydino of the Omsk Railways. Thus, a principal input in the lake balance consists of snowmelt flowing from the catchment area and precipitation on the lake surface.

Rain water with a percentage of 80% in an annual precipitation sum for many years penetrates into soil and evaporates from it without creating a surface runoff because of hot summers and soil dryness. Only lakes with deep basins are fed with ground water.

A main output component of the lake water balance is evaporation on the water surface, which is constant during a year. Within a cold period evaporation on the snow surface is insignificant. Expeditions of State Hydrological Institute carried out in 1956 and 1957 [2] showed an evaporation discharge in the snowmelt time (April) is around 8-10 mm and 550-700 mm within a warm period, respectively.

Lakes are filled when the snowmelt period begins in the first half of April and lasts 10-12 days till the end of April – first decade of Mai. A water level rise in the period of seasonal flood is in a range of 0.3…0.4 m on average and 0.1…0.2 m in low-water years. After filling a high level of water remains in lakes during 2…4 and up to 15…20 days. In the middle of Mai a level of lake water begins to fall gradually and continuously; in summer and autumn it decreases by 0.3…0.5 m on average. The precipitation on the lake surface in a warm year period reduces considerably a water level falling-down rate. The lowest possible level of water in lakes is usually registered in late October. Every year at this time shallow lakes tend to dry out. A level of deeper lakes, which remain filled with water till the end of autumn, hardly changes during winter time. Water bodies with a depth below 1 m freeze solid to the bottom every year.

3. Restoration of Lakes

Lakes in the valley of Kamyslovka form a complex hydrological system. In the 1920-s they used to be 1.5…2.0 m deep with a water mineralization value of 1.4…6.0 g/l, while nowadays most of them are shallow-water ponds with a depth of 0.4…0.7 m and in certain periods a water mineralization value ranges up to 50 g/l or even 70 g/l. Moreover, many of them dried out completely during drought years (1951…1953, 1974…1975, 1998…2000 and 2010) [3] leaving in the lakebed a 1.0…1.5 cm layer of salts being blown by the wind. Lakes Peschanoye and Severnoye, Maryanovsky District, Lake Kamyslovoye, Moskalensky District (Elita), etc., tend to dry out every 4-6 years.

A hydrological analysis shows no changes in the total amount of moisture coming to the territory for many years. A water balance of lakes suffers mainly from man-made transformations in the water catchment structure provoked by economic use of lands and road construction of higher categories. Numerous shallow dams in ravines caused the shrinkage of natural water catchment areas, in several cases more than twice. In these conditions a poor natural runoff (7…10 mm) in the residual catchment
areas is localized in depressions and fails in reaching lakes. In years with a less changed runoff a degree of water mineralization in lakes remains almost constant 5…15 g/l, in shallow and deep lakes (with a surface up to 20…40 ha) – 1.2…2.0 g/l. Then, a changing hydrological regime led to a dramatically risen water mineralization value in lakes. For instance, a water mineralization level in Lake Solenoye was 11.46 g/l in August 1948 and 14.57 g/l in Lake Krivoye in the same period, whereas in 1953 these values increased to 19.82 g/l and 28.5 g/l, respectively.

The growth of water mineralization is hardly related to a substantial increase of salt resources. A principal factor responsible for mineralization increase in lakes is supposed to be the evaporation on water surfaces, which are too large in changed runoff conditions.

As known, in the Kamyslovskaya valley there is no runoff into lakes during low-water years with a small amount of rainfall. Naturally, a water level in lakes falls, as well as their volume decreases, at the same time reducing water levels and volumes inevitably provoke the growth (approximately by two times) of water mineralization in lakes and water salinization in the floodplain for ground waters lying near lakes at a depth of 1.0…1.2 m make an important contribution to the evaporation and accumulation of salts in soil. As estimated, a share of salts in the surface of some areas ranges up to 6% and a level of mineralization is 60 g/l.

Therefore, a floodplain part of the valley may be used in economy provided that the desalination of lands is carried out, and, more importantly, a hydrological regime of lakes is stabilized alongside with their demineralization [4].

Water demineralization in water bodies represents the most complex and challenging issue because it is necessary to drain salt water out of them and supply fresh water from other sources. In this case a reasonable use of fresh water resources from the local runoff makes a problem less difficult and furthers the efficient utilization of the surface runoff.

To assess a possibility to rely on a local runoff in the economic revival of the Kamyslovka valley we estimated hydrological parameters of the runoff and water balance in sections formed when arranging the valley economy. For this purpose we selected 6 sections within the boundaries of Omsk Region, here, a zero point is coincident with the western boundary of Lake Plovinnoye near the settlement of Pervotarovka, Isilkulsky District. Other sections are determined according to inter-farm dams. The data obtained show insignificant amounts of an annual runoff (Table 1), even under assumption, a natural drainage area is taken into account when calculating a volume of inflow; in fact it is almost twice smaller than values presented (Figure 1).

To evaluate an alternative of stabilizing the water balance of lakes and demineralizing them, a prediction calculation for Lake Piketnoye is conducted (a factual drainage area $F_D=56$ km$^2$ and lake surface area $f_s=9.25$ km$^2$). As an additional inflow element we considered purified production and household sewage, which also helps demineralize water in the lake.

| № of sections | Drainage area, km$^2$ | Average long-term runoff, mm | Flow rate $Q$, m$^3$/s | Flow rate $W$, mln.m$^3$ | $Q_{PS}$, m$^3$/s | $W_{PS}$, mln.m$^3$ |
|---------------|------------------------|-------------------------------|------------------------|------------------------|-------------------|---------------------|
| 1             | 234                    | 7.86                          | 0.058                  | 1.84                   | 0.037             | 0.443               |
| 2             | 290                    | 7.86                          | 0.072                  | 2.28                   | 0.046             | 0.549               |
| 3             | 1091                   | 7.86                          | 0.272                  | 8.57                   | 0.174             | 5.488               |
| 4             | 1202                   | 7.86                          | 0.299                  | 9.44                   | 0.191             | 6.045               |
| 5             | 457                    | 10.1                          | 0.146                  | 4.61                   | 0.094             | 2.953               |
| 6             | 508                    | 10.1                          | 0.163                  | 5.13                   | 0.104             | 3.282               |

A volume of the lake with a depth of 0.6 m is determined to be $W_{D}=3.7$ mln.m$^3$. For an average mineralization value of water 20 g/l resources of salts in the lake are $S_{O}=74\times10^3$ t.

As known, a seriously shrinking real drainage area because of a decreasing runoff has a consequence that significant lake surfaces dry out and a value of their mineralization rises. In such
cases it makes sense to reduce a lakescape via deepening. Here, the deepening is planned to 3.0 m and in future the lake can be used for fish-breeding. A surface of the lake will get smaller to 1.23 km².

We discussed all possibilities salts can be input into this water body:
- an amount of salts from the drainage area for a layer \( Y = 7 \) mm and a value of mineralization \( q_{CT} = 0.25 \) kg/m³ is determined \( S_{CT} = 95.85 \) t;
- an annual amount of salts supplied with the precipitation for a layer \( KX = 320 \) mm, \( q_{OC} = 0.05 \) g/l \(- S_{OC} = 19.63 \) t;
- a salt input of Neogenic and Quaternary deposits for a module of subterranean runoff \( M_{IP} = 0.08 \) l/s per km² or 2.52 mm of a runoff layer for a drainage area \( F_{IP} = 54.77 \) km², a value of mineralization \( q_{IP} = 1.5 \) g/l is as much as \( S_{IP} = 207.03 \) t.
- a salt input of Oligocene waters for a runoff module \( M_{OI} = 0.01 \) l/s km² or 0.32 mm and a level of mineralization \( q_{OI} = 5 \) g/l \(- S_{OI} = 87.63 \) t.

In this case a total amount of salts is calculated:
\[
\sum S = S_{CT} + S_{OC} + S_{IP} + S_{OI} = 95.85 + 19.63 + 207.03 + 87.63 = 410.142 \text{ t.}
\]

Here, a total volume of water is:
\[
\sum W = W_{CT} + W_{OC} + W_{IP} + W_{OI} = (0.3834 + 0.3936 + 0.1382 + 0.0175) \cdot 10^6 = 0.933 \cdot 10^6 \text{ m}^3
\]

For the annual evaporation on the surface \( Z = 700 \) mm a volume of evaporated water is \( W_{ne} = 0.861 \cdot 10^6 \text{ m}^3 \).

Taking into account the evaporation on the lake surface \( 0.861 \cdot 10^6 \text{ m}^3 \) and a volume of water remained in the lake \( W_{OI} = 3.7 \cdot 10^6 \text{ m}^3 \), a level of mineralization \( q_{OI} = 20 \) g/l, an averaged value of mineralization will be \( q'_{OI} = 19.37 \) g/l in autumn.

Furthermore, in the valley there is a flow of infrared water in the alluvial apron with an average width 12 m and averaged filtration coefficient 1.5 m/d. In this case a volume of annual ground water input from this part is as high as \( W_{IP} = 44.6 \text{ m}^3 \).

The cut of evaporation losses and involvement of the infrared flow will support a positive balance of the lake, and a water mineralization value in the restored watercourse will be \( q''_{OI} = 18.644 \) g/l.

In the practice of water use we know that amounts of water taken from water sources should be brought back after certain qualitative or quantitative transformations [5]. Unless water-draining systems are built, there is a problem of sewage recycling. In this case, sewage is stored in special underground tanks – septic system and discharged then. A problem of production and household sewage recycling is to be solved in settlements located along the Kamyshtlovsky log, ground waters are frequently overfilled with drained water, what leads to overflooding. In these conditions a use of water bodies located in the valley as an intake structure of purified household sewage can make an additional contribution to the solution of a problem of overflooding. In its turn the discharge of biologically purified water [6] cuts a mineralization value of water bodies. On average, one lake can receive 800 m³ per day or 292000 m³ per annum sewage produced by one farm and one farm center; with this volume a value of lake water mineralization in the first year is \( q_{1f} = 17.65 \) g/l.

Taking into consideration an average year with all its input and output components of water-salt balance, we can determine a mineralization value of water in the water body. As calculated, a further year reduces a mineralization value of lake water to \( q_{2f} = 15.36 \) g/l. Further estimations show that in five years a value of mineralization ranges to \( q_{5f} = 12.23 \) g/l given that an optimal reorganization plan of water bodies is realized and additional water runoff is taken into account, in 27 years it stabilizes with a value of 4.5…5.5 g/l.

4. Conclusion
The biggest territory of the Kamyshtlovsky log is covered with a chain of shallow lakes with no outlets and different values of mineralization; their water levels fall dramatically after seasonal floods and many of them even dry out.

Water bodies with a high level of mineralization are the reason for the expansion of fruitless saline and alkaline soils, their salinity increases near the floodplain.
The environmental improvement and revival of natural grasslands efficiency in the valley are possible if a soil mineralization parameter is reduced through the restoration of water bodies and stabilization of their water balance.

The desalinization of lakes via deepening and reducing their lakescapes, as well as supply of purified sewage from rural settlements is an effective step to improve the condition of soils, although it is a long-term process. A proposed model for Lake Piketnoye is similar to the drainage of 18 lakes located further upstream.

5. Reference

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