Modern Technologies of Alkalized and Sodic Soils Reclamation

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Abstract. The technology of desalination of fine-textured soils using deep tillage, leaching operations and chemical reclamation agents includes the calculation of doses of ameliorants and leaching requirements, methods and timing of reclamation, soil treatment, selection of crops, and the need for fertilizers on reclamation lands. The stages of preparation of the fields before the application of ameliorants are reviewed. Initially, the fields are divided into lots, the location of loose ameliorants clamps is determined. The options for overall and selective land reclamation are considered. When conducting selective reclamation, it is necessary to locate the solonetzic spots and mark them with range poles. The options for cultivating the soil of irrigated lands characterized by increased density of the subsurface soil horizon of more than 1.4 t/m³ are reviewed. The most pressed are the solonetzic soils with a poor structure or without it. The most preferred methods of cultivating degraded soils (deep loosening or plowing) are identified, which are one of the necessary techniques to provide the greatest depth, degree and speed of soil desalinization. The options for leaching of chloride-sulfate loamy soils, chloride-sulfate salinization and soda salinization are considered.

Introduction

Reclamation should be aimed at reducing the content of exchangeable sodium in the absorbing complex, improving the chemical and hydrophysical properties of soils, and creating a highly fertile root layer. When developing sodic soils under irrigation, during the reclamation and operational periods, the processes of repeated alkalization and salinization of sodic and zonal soils should be completely excluded.

When choosing a method and technology for the reclamation of solonetzic soils to ensure soil desalinization and prevent alkalization and salinization of soils, it is important to consider the content of exchangeable sodium, gypsum and carbonate depth and reserves in solonetz, the chemical mechanism of solonetz and zonal soils salinization, and also the amount of secondary absorbed sodium and secondary soda formed as a result of chemical exchange. Based on the chemical, physico-chemical properties of neutral solonetzic soils and their changes under irrigation, the following basic land reclamation methods can be applied to increase their fertility: chemical, agrobiological, complex. When developing

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irrigated neutral solonetzic soils, the chemical reclamation method is most effective. It should be applied first of all, on gypsum-free and chloride, sulfate-chloride and chloride-
sulfate solonetzic soils with gypsum at great depth [4,9].

1. Materials and Methods

1.1 Soil Treatment

Most irrigated lands are characterized by increased density, starting from a subsurface
horizon of more than 1.4 t / m$^3$. The most severe compaction occurs on solonetzic soils
with a poor structure or without it. This, on the one hand, worsens the conditions of
plants' root system development, and on the other hand, it greatly complicates the removal
of water-soluble salts excess during irrigation and leaching. Therefore, deep loosening or
plowing is one of the necessary techniques that provide the greatest depth, degree and speed
of soil desalination.

Deep loosening should be carried out on soils with hardpan thickness of more than 0.2-
0.4 m, with a bulk density in the upper layer of 0.6 m more than 1.30 t/m$^3$ (for high-humic
soils); 1.45 t/m$^3$ (for low-humic soils).

With deep loosening, the soil moisture in the treated layer should not exceed 60-70% of
the lowest moisture capacity so that the soil does not smear and adhere to the cultivator.
When cultivating rice, perennial grasses and crops of slow sowing on heavy textured soil,
deep loosening is advisable to be carried out simultaneously with pre-sowing or spring soil
treatment.

Deep loosening reduces soil density by 20-30% and increases the soil permeability (E)
by 10-15 times. The duration of the aftermath of chisel plowing is 2 years, and the
aftermath of deep loosening is 3 years on the land of rice crop rotation [2,3,7].

The leaching of chloride-sulfate loamy soils of rice crop rotation should be carried out
amid moling to a depth of 35 - 40 cm or non-moldboard loosening with a subsurface
cultivator to a depth of 45-50 cm. This ensures desalination of a layer as deep as 1 m in the
first year.

On chloride-sulfate clay-textured soils with amount of salts from 0.6 to 2.2, in addition
to moling to a depth of 35-40 cm, fine drains 0.5-0.6 m deep are cut every 10 m after
sowing rice, perpendicularly to the mole drains, with the outlet to the spillway into the
drainage collector. Continuous mole drains cutting is carried out by the mole draining plow
КШ-2Б, laying of molehills every 70-100 cm[6].

On soils of sodium-carbonate salinization, leaching is combined with chemical
reclamation. To ensure the penetration of sulfuric acid solution to a target depth, accelerate
the removal of water-soluble salts and neutralize the alkaline reaction, one-time
paraplowing or moling to a depth of 55-65 cm is carried out [1,3,7].

1.2 Reclamation

Ameliorants are chemicals containing calcium that, when introduced into the soil, can
improve its physical and chemical properties (gypsum, phosphogypsum, clay-gypsum), as
well as acidic ameliorants (sulfuric and nitric acids, industrial wastes and other substances).
Ameliorant calcium displaces absorbed sodium, which is washed out as sodium sulfate
[3,4,8].

Loose ameliorants (gypsum, phosphogypsum, clay-gypsum) can be applied with
spreaders of mineral fertilizers, lime, gypsum and organic fertilizers (table 1).

It is better to use spreaders that in one pass can scatter the estimated amount of
ameliorant. At the same time, the ameliorant spreading areas at each pass must overlap each
other. If there are no necessary machines, it is required to calculate the number of passes
required to make the estimated dose.
In fodder crop rotation, the ameliorant is applied after harvesting early ripening grains (barley, winter wheat), silage crops of corn, feed mixtures), or plowing alfalfa. In rice crop rotation, the introduction of ameliorant is better to combine with the techniques carried out on the reclamation field, which will ensure the implementation of the whole range of works that enhance the effect of chemical reclamation.

Table 1—Characteristics of substances used for chemical reclamation of saline and saline soils

| Name of meliorant                  | Base ameliorant | Fertilizing substances                        | The pH of the suspensions |
|-----------------------------------|-----------------|-----------------------------------------------|---------------------------|
| Pinoyps                           | Gypsum 68-82%   | -                                             | 7.2-7.8                   |
| Gypsum                            | Gypsum 70-75%   | -                                             | 6.8-7.5                   |
| Phosphogypsum                      | Gypsum 90-95%   | $P_2O_5$ – 1.3-5%; $P_2O_5$ – 0.6-2.5%; trace elements – 1.5% | 2.5-4.0                   |
| Spent $H_2SO_4$                    | Sulfuric acid   | Organic additives 4-6%                         | 1.0-1.5                   |
| Electrolyte for steel etching     | 84-86%          | Cepa – 4%                                      | 2-3                       |
| Waste rock                         | Iron sulphate 8-15% | $P_2O_5$ – 0.01%; $K_2O_5$ – 0.25%; trace elements, humus residues, coal residues 8% | 3-5                       |
| Waste rock treated with 5% $H_2SO_4$ | Calcium sulphate, iron, aluminium | $P_2O_5$ – 0.04%; $K_2O_5$ – 0.33%; trace elements, humus residues, coal residues 8% | 3                           |

If the soil contains neutral solonetz in its cover, the introduction of ameliorant can be combined with the intensive use of the ameliorative field when cultivating one or two crops per year. For example, in spring, add ameliorant and dung, plow up, plan the surface, water it, and then sow buckwheat in early August, or after harvesting winter or early spring crops, add ameliorant, plow it up, level the surface, water and sow crops for green manure or green fodder [1,3,5].

If the soil contains carbonates in the reclaimed layer of solonetz, sulfuric acid can be used for their reclamation, which is introduced directly into the carbonate layer using a mole plow $KT_D$ - 0.45. After 5-7 days, the soil is plowed with the triple-deck plow ПТН-3-40 to destroy the solonetzic horizon and mix it with the subsolonetz, in which as-precipitated gypsum is formed. After 2-3 months, leaching is done in the reclaimed area.

On high-carbonate soda solonetzic soils of loamy or light-clayey texture with absorbed sodium content in the upper 60 cm layer of less than 50% of the exchange capacity, sulfuric acid is effectively added to the surface of the paddy field in the form of a 1% solution.

On carbonate soda alkali-saline soils of heavy texture with an absorbed sodium content of more than 50% of the exchange capacity in the upper meter layer, a 50% dose of sulfuric acid must be introduced in the form of a 5-15% solution into the mole drains, and the second half in the form of 1 % solution on the surface of the paddy field.

2. Results

The land reclamation in the present technologies is supposed to be started in areas
provided with efficient drainage and planned surface.

If planning has not been carried out for a long time at the site under reclamation, it should be carried out taking into account the peculiarities of the soil cover. It should be remembered that, according to the usual planning method, cuts of no more than 20 cm are allowed on saline lands and solonetzic soils.

To eliminate small surface irregularities, current (operational) planning is carried out by land smoothers П-4, ПА-4, sweeper harrows ШБ-2,5 and a long span blade leveler Д-719 [3,5].

In the rice fields, the average natural slope should be preserved. Often it is impossible to achieve the required uniformity with a single-stage planning before acidification and leaching. Therefore, the planning is carried out in two stages: prior to cutting the leaching checks, a preliminary planning is done, and before the introduction of ameliorants, the final one is carried out inside the checks. Before the application of ameliorants, the fields of non-rice crop rotations are divided into lots, the location of the clamps with loose ameliorants is determined during selective reclamation. Also it is necessary to locate the solonetzic spots and mark them with range poles (table 2).

Table 2-Technological map for washing saline lands with simultaneous cultivation of rice

| N. | Name of works                          | Terms and conditions                                      |
|---|----------------------------------------|-----------------------------------------------------------|
| 1 | Layout (capital)                       | Spring period. Layout accuracy ± 5 cm                     |
| 2 | Plowing to a depth of 22-25 cm         | Spring-summer                                             |
| 3 | Cropping to a depth of 35-40 cm (crevice to a depth of 35-40 cm) | Spring. Deviation from the specified depth ± 5 cm         |
| 4 | The layout consists of several passages | Spring. Layout accuracy ± 5 cm                            |
| 5 | Rice sowing                            | After the current layout                                  |
| 6 | Cutting of temporary shallow drainage 50-60 cm | After cutting moles and sowing rice. The deviation from the specified depth shall not exceed ± 2 cm |
| 7 | Cutting of output furrows with a depth of 45-50 cm | After cutting the temporary drainage and sowing of rice. The deviation from the specified depth shall not exceed ± 5 cm |
| 8 | Washing with water                     | Irrigation rate 22-25 thousand m3 / ha                    |

The breakdown of the fields into lots is carried out in such a way that one refueling of the machine bed is a multiple of the length of the working path of the machine (1).

\[
P = \frac{C \cdot 10^3}{W \cdot D}
\]

where \( P \) is the length of the path of the machine, m;
\( C \) - cargo capacity of the machine, t;
\( W \) - operating width, m;
\( D \) - dose of gypsum, t / ha

The distance between the clamps is calculated by the formula (2):

\[
W = \frac{B \cdot P}{D}
\]

where \( B \) is the distance between the clamps, m;
\( W \) - operating width, m;
\( P \) - the length of the path of the machine, m;
The mass of lamps (M) is determined based on the following relationship:

\[ M = \frac{D \cdot A}{N} \]  

(3)

where M is the mass of the ameliorant in a clamp, t;
D is the dose of gypsum, t / ha;
A - the area of cultivated field, ha;
N - the number of collars.

Liquid ameliorants at high doses should be distributed along the surface with irrigation water. To do this, the reclaimed area is divided into ordinary irrigation strips. The width of the lanes is assigned to a multiple of the operation width of agricultural machines. Usually it is 20-30 m.

The supply of sulfuric acid is as follows. In the check near the water ejector soil cushions are fitted with faucet tanks filled with concentrated sulfuric acid. Preliminarily, the corresponding amount of irrigation water, which provides the required concentration of ameliorant entering the check, is calculated by the formula:

\[ W = \frac{a \cdot (100 - C)}{100 - C} \]  

(4)

where W is the amount of irrigation water required to dilute the acid, m³ / ha
a - the amount of acid required for reclamation, t / ha;
b - initial (default) acid concentration;
C - concentration of the solution for acidification.

All acid supplied to the check must be absorbed. Disposal is strongly forbidden. For quick and uniform filling of checks, acid is fed into the wash water through 2-3 ejectors.

Before applying phosphogypsum or milled raw gypsum, it is necessary to adjust the scale, check the width and evenness of the ameliorant spreading, depending on the operating mode of the machine. To do this, make several passes on the main modes of machine operation. In fact, the dose applied in one pass of the unit can be determined by arranging the measuring shields along the operating width and along the path of the machine with the shield area of 1 m². The weight of the ameliorant (grams) that fell on it must be multiplied by 10000 and we will get the dose in tons per 1 hectare. The dose of ameliorant within the sifting width should not fluctuate by more than 25%. You can adjust the evenness of the ameliorant spreading across the operation width of the machine by changing the position of the caster: moving it forward increases the spreading of the ameliorant in the middle of the gripper, and backward - along the edges of the spreading strip [4]. Dose adjustment for machines with a conveyor drive from the power take-off shaft is carried out by changing the speed.

To calculate the adjustment factor P for a given batch of ameliorant is possible by the formula:

\[ P = \frac{R_a}{R_t} \]  

(5)

where \( R_a \) and \( R_t \) are the actual and tabular rate of ameliorant application.

Later, when the gate valve of the portioning device is adjusted to a predetermined dose, it is necessary to consider the adjustment factor. When using spreaders of organic fertilizers it is necessary to remove the top spreader reels. That contributes to a more even ameliorant spreading in operation width [1,2]

3. Discussions
The basic methods of soil desalinization are leaching and watering. In rice crop rotations desalinization is reached due to the leaching provided by the cultivation of rice. In forage and other crop rotations desalinization of saline soils is achieved at the expense of vegetation and of water-charging irrigation.

In rice rotations on neutral saline soils after the appropriate soil treatment and rice sowing the check is flooded. At the time of the flood the water disposal from the check into waste ditches network is closed. At this time salts dissolve in the soil. After sprouting of rice seeds water is discharged from the checks by means of drainage network. When growth above ground is seen, the check is flooded again and the water level is supported under a given irrigation regime during the whole growing period of rice. Soluble salts continue to leach in the water filtration process in mole drains, and then it is discharged into the drainage network. In this case, the rice irrigation rate goes along with the leaching one.

On soils of sodium-carbonate salinization after the general grading, depending on the slope of the terrain, the reclaimed land is divided into leaching checks (or stripes) of rectangular or square shape. The sizes of these checks must meet the requirements of mechanized soil cultivation. Moreover, the level difference between the sides of leaching check should not exceed 5-7 cm. Size of leaching checks can reach an average of 2 hectares. In the places where check dams will be located on a strip of 6 m, ameliorant is placed (before cutting the dams)in an amount of the maximum demand of the treated area. Then low earth barriers are made. The corners are made with a bulldozer or scraper and planning inside checks is carried out. On existing engineering rice systems there is no need for cutting checks. [3,4,10,11].

When conducting chemical reclamation the check soil is loosened by one-time soil slotting or moling to a depth of 0.6 - 0.7 meters. Due to this operation very favourable conditions for the penetration of acidic solutions and leaching water to a target depth are set up. This event significantly accelerates the neutralization of the alkaline reaction of the entire depth of the loosened soil and salt removal by means of the groundwater and drainage outflow.

To organize leaching one should use an existing or make a new irrigation network according to the requirements of mechanization and land reclamation. To account for the wash water, the weirs must be installed. The overflow of water from one leaching checks to the other is not allowed.

Independent supply of temporary sprinklers on separate leaching checks is dictated by the need to prevent mixing of saline water from separate checks and ensures the supply of clean wash water when leaching. To prevent soil erosion in the wash checks with water supply it is recommended to use tubular or wooden emptying sluice.

It is strictly prohibited to dump the rinse water from the surface of checks in the process of chemical reclamation [3,4,5,12,13].

**Conclusions:**

- desalinization of soils according to existing technologies is possible in areas provided with efficient drainage and a planned surface;
- in rice checks, the average natural slope should be preserved throughout the entire treated area;
- to eliminate minor salinization, it is necessary to leach across the growing culture;
- for all methods of washing acidified soils it is recommended that fields should be flooded from the middle of the mid-slope along the center line with the successive expansion of the washed strip between drains.
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