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Methods of reclamation of neutral salt flats

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Abstract. To increase the fertility of neutral salt pans and improve their physico-chemical properties under intensive irrigation, it is necessary to apply a set of measures. Reclamation of saline soils should be aimed at reducing the content of exchangeable sodium in the absorbing complex, improving the chemical and water-physical properties of soils and creating a highly fertile root-inhabited soil layer. When developing salt flats under irrigation conditions, both in the reclamation and in the operational period, the processes of secondary alkalinization, salinization and salinization of salt flats of zonal soils should be completely excluded. When choosing a method for reclamation of salt pans, which ensures soil desalination and prevents their alkalinization and salinization, it is necessary to take into account the content of exchangeable sodium, the depth of occurrence and reserves of gypsum and carbonates in salt pans of salinization of salt pans and zonal soils, as well as the amount of secondary absorbed sodium and secondary soda formed as a result of exchange reactions.

1 Introduction

Based on the chemical, physico-chemical properties of neutral salt pans and their changes under the influence of irrigation, the following basic methods of land reclamation can be applied to increase the fertility of the latter: chemical, agrobiological and complex.

2 Materials and methods

When developing neutral salt wells in irrigation conditions, the chemical method of reclamation is most effective. It should be used, first of all, on gypsum-free and deep-gypsum, chloride, sulfate-chloride and chloride-sulfate suns. Meliorants are chemicals containing calcium salts that can improve its physical and chemical properties when applied to the soil (gypsum, phosphogypsum, clay gypsum), as well as acidic meliorants (sulfuric, nitric and acidic industrial waste) and other substances. Calcium meliorant displaces absorbed sodium, which in the form of sodium sulfate is washed out by outgoing rivers of water.

Dilute mineral acids (sulfuric, nitric) and acidic industrial waste can be used for reclamation of carbonate neutral salts. Sulfuric acid introduced into the carbonate horizon should be spent on the formation of freshly deposited gypsum as a result of its interaction

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with calcium and magnesium carbonates. The resulting amorphous gypsum, which has a high activity, contributes to the substitution of exchangeable sodium in the soil absorbing complex for calcium, thereby improving the water-physical, physico-chemical, agrotechnical and other properties of soils.

A valuable chemical meliorant is the waste rock of the coal industry (Bobkov, Dokuchaeva, 1973), which is a crumbly mass in which particles ranging in size from 1 to 10 mm make up more than 60%. The terricon rock is rich in iron, calcium, and sulfur compounds. Sulfur is oxidized in the soil to sulfuric acid. PH is acidic, about 3. In addition, it contains nutrients - phosphorus, potassium, trace elements. According to available data, 80-100 kg of iron, 5-10 kg of phosphorus, 100-120 kg of gypsum, 5 kg of manganese, 100 g of zinc, copper per I ha of area are introduced from 1 ton of meliorant. When adding a terricon rock from 20 to 40 t / ha, water permeability increases, the water-air regime of soils improves, and the presence of a certain number of elements of mineral nutrition in it contributes to the enrichment of soils with nutrients and increases crop yields.

The calculation of the dose of gypsum or phosphogypsum for the reclamation of neutral deep-saline (deep-saline) and saline salt flats with a salt horizon deeper than 50 cm is carried out according to the formula:

$$\mathrm{G} = 0{,}086(\mathrm{Na} - 0{,}03 \cdot E) \cdot h \cdot \vartheta \tag{1}$$

where G - is the dose of gypsum $CaSO_4 + 2H_2O$, (phosphogypsum), t/ha;

Na - is the content of exchangeable sodium, mg-eq./100 g;

0,03 - the proportion of inactive sodium;

E - is the absorption capacity, total exchange cations, mg-eq./100 g;

H - is the capacity of the reclaimed layer, cm;

ϑ - volume weight of the soil, g/cm^3;

0.086 - is the coefficient corresponding to 1 mg-eq. gypsum.

The dose of gypsum or other chemical meliorant needed to displace exchangeable sodium from salt pans and neutralize secondary soda during the development of saline and partly saline salt pans should be determined on the basis of experimental washings in the field and laboratory conditions with the introduction of chemical meliorants. Very tentatively, this dose can be determined by calculation. The amount of gypsum required to displace exchangeable sodium, including secondary, and neutralize the bicarbonate of soda formed during washing can be calculated in total according to the formula (1) and the empirical formula (2) proposed by A.A. Popov:

$$\mathrm{G} = 0{,}086 \cdot \mathrm{K} \cdot h \cdot \vartheta \tag{2}$$

where h - is the capacity of the reclaimed layer, cm;

ϑ - volume weight of the soil, g/cm3;

0.086 - is the coefficient corresponding to 1 mg-eq. gypsum

K - is the total value of secondary absorption of sodium and secondary soda mg-eq./100 g of soil. For gypsum-free and deep-gypsum chloride salts, the K value can be assumed to be equal to 3.0 - 2.5; sulfate–chloride 2.5 - 2.0; chloride-sulfate 2.0 - 1.5.

Increasing the fertility of salt pans can be achieved by using clay gypsum. In the south-eastern regions of the Rostov region, clay gypsum deposits are very large, and the gypsum content in them is 60%, and sometimes 90%.

The dose of application of clay gypsum is calculated by the formula (3).

$$\mathrm{G} = 0{,}086 \cdot \mathrm{Na} \cdot \mathrm{K}_1 \cdot h \cdot \vartheta, \text{ t/ha} \tag{3}$$

where Na - is the content of exchangeable sodium, mg-eq./100 g;

h - is the capacity of the reclaimed layer, cm;

ϑ - volume weight of the soil, g/cm3;

0.086 is the coefficient corresponding to 1 mg-eq. gypsum.

K_1 is the coefficient of recalculation of clay gypsum to pure gypsum, which is calculated taking into account humidity and the percentage of gypsum content in clay gypsum.

It is better to use chemical meliorants against the background of reclamation treatment, which provides deep loosening of the salt profile, its crumbling and mixing of the meliorant with the soil.

Table 1. Gypsum content in clay gypsum, %

Humidity of the meliorant, %	Percentage of pure gypsum in clay gypsum, %							
	65	70	75	80	85	90	95	100
30	2,20	2,01	1,91	1,79	1,69	1,58	1,51	1,43
25	2,01	1,88	1,79	1,67	1,57	1,48	1,41	1,34
20	1,90	1,76	1,67	1,56	1,47	1,39	1,33	1,25
15	1,80	1,66	1,58	1,47	1,39	1,30	1,25	1,18
10	1,70	1,58	1,49	1,39	1,31	1,23	1,17	1,11
5	1,62	1,48	1,41	1,33	1,24	1,17	1,12	1,06
0	1,54	1,41	1,34	1,25	1,18	1,11	1,06	1,00

Sulfuric acid or acidic industrial wastes can be used for reclamation of carbonate, primarily salt-marsh (salt-marsh) gypsum-free and deep-gypsum salt salts of chloride and sulfate-chloride type, which are subjected to the greatest alkalinization and secondary salinization during the process of salinization.

The dose of sulfuric acid is calculated according to the formula (4) by V.P. Bobkov, which takes into account the total alkalinity, the presence of carbonates and the content of exchangeable sodium.

$$\mathrm{DM} = \frac{0{,}049 \cdot (\mathrm{Na} + S + \mathrm{CO_2}\,\text{карб.}) \cdot h \cdot \vartheta \cdot 100}{2P},\ \text{t/ha} \tag{4}$$

where DM - is the dose of meliorant, sulfuric acid, t/ha;

0.049 - is the amount of the applied chemmeliorant in grams, corresponding to 1 mg-eq. sulfuric acid;

S - is the number of mg-eq. $HCO_3 + CO_3$ contained in an aqueous extract;

CO_2 carb. – the content of carbonates in the soil, %;

P - is the percentage of the chemmeliorant (concentration of sulfuric acid).

In order to cause the destruction of the mineral part of the soil and the loss of organic matter, sulfuric acid is introduced in a dilution (3-15% solution), which will be quite sufficient to form the necessary amount of highly dispersed gypsum used for soil desalination. The acid can be applied in combination with gypsum (clay gypsum) and mineral fertilizers.

The effectiveness of chemical reclamation of neutral salt pans is achieved under the condition of the use of preliminary or operational washings, the introduction of organic and mineral fertilizers, the introduction of perennial grasses into crop rotations and the provision of a washing irrigation regime.

When the content of salt salts in the soil complex is more than 25%, chemical meliorants are applied to the entire area. If saline soils are less than 25% and zonal soils are not saline (not alkaline), then chemical meliorants are applied only to saline spots.

Chemical meliorants are used for reclamation of salt pans that meet the requirements of GOST in terms of the content of the active principle and the fineness of grinding. Terricon rock is used burnt out and not burnt out, weathered), crumbly, having an acidic reaction.

It should be borne in mind that clay gypsum, as a meliorant, is effective, provided that preliminary desalination irrigation is carried out after its introduction into the soil and a flushing irrigation regime is provided. If these conditions are not met, as studies have shown, the processes of secondary salinization (due to the accumulation of sodium sulfates) and salting of salt salts are observed.

The best dose is 10-12 tons of clay gypsum per 1 ha. At the same time, the positive effect of this meliorant can be traced for 5-6 years. The high efficiency of clay gypsum is established during rice sowing. To achieve significant effectiveness of clay gypsum, it is necessary to achieve uniformity of its embedding in the soil. Manure spreaders with high productivity are used in production conditions. On rice checks, clay gypsum is applied under the main plowing or a freshly plowed field with further plowing with a plow without ploughs. This will create the best conditions for moistening and mixing the chemmeliorant with the soil.

Against the background of clay gypsum, nitrogen and phosphorus fertilizers are effective. Their norms for rice are as follows: nitrogen fertilizers 120 kg /ha; phosphorus fertilizers up to 120 kg/ha. Since salt pans are rich in potassium, potash fertilizers are not recommended. The introduction of manure for rice culture gives a positive effect in the first two years, and in the future there is an accumulation of under-oxidized organic residues in anaerobic conditions and toxic substances for plants are formed, which sharply reduces the rice yield.

Therefore, it is more expedient to replenish the supply of nutrients when cultivating a flooded crop with mineral fertilizers.

During the acidification, sulfuric acid is delivered to the field in iron containers with a tap at the bottom for draining the liquid.

Dilute sulfuric acid is applied against the background of deep plowing or crothodrenes.

According to available research, the introduction of sulfuric acid along the crotodrenes into the horizon of the maximum accumulation of carbonates (20-40 cm) with subsequent three-tiered plowing is effective. To introduce acid in this method of reclamation of salt pans, a KTD- 0.45 A molehill is used, which is equipped with a device for supplying liquid to molehills to a depth of 20-40 cm. The mole is aggregated with tractors developing a traction force of over 50kN. You can also use other molehills and schelerezes, on which acid tanks are installed, equipped with pipelines. According to them, the meliorant is fed into the reclaimed carbonate layer of the soil. After 5-7 days of interaction of sulfuric acid with carbonates, reclamation three-tiered plowing with a PTP-40 plow is carried out to destroy and mix the salt horizon with the salt horizon, in which freshly deposited gypsum has formed, which has increased activity of interaction with the soil-absorbing complex of the soil. After 2-3 months, a two-stroke washing is carried out on the reclaimed area to saturate first a half-meter, and then a meter layer to the maximum (lowest) moisture capacity of the soil. During washing, the interaction of ⟦CaSO⟧_4 with the soil-absorbing complex increases. The water-soluble salts formed during acidification and, in particular, the reaction product - sodium sulfate are washed into the underlying horizons. The site where the acidification is carried out must be provided with a good drainage network. The number of washings and the washing rate are determined on the basis of control analyses on the content of water-soluble salts and humidity in the washed layer (0.5 - 1.0 m).

Various agricultural crops can be cultivated on acidified plots: rice, alfalfa, barley, wheat, sorghum, Sudanese grass, sorghum-Sudanese hybrid, sunflower, corn for silage. Agricultural crops after acidification are grown with the usual agricultural techniques adopted in the farms of the region.

The leading role in the agrobiological method of reclamation belongs to deep reclamation treatment aimed at creating a cultivated arable and root-inhabited layer with the involvement of soil gypsum from the underlying horizons, due to which self-reclamation is ensured. In addition to the involvement of soil gypsum in the arable layer, deep reclamation plowing, mechanically acting on salt pans, reduces the density, improves the water-air regime of soils.

The agrobiological method of reclamation under irrigation conditions can be applied on high gypsum salt wells with a supply of gypsum sufficient to displace exchangeable sodium from the salt horizon. When justifying this method of reclamation, it is necessary to take into account that neutral saline soils can enter into a complex with zonal saline soils that have soda salinity and need chemical reclamation. In addition, it should be borne in mind that part of the gypsum in salt pans (up to 40-60%), especially during washing and rice sowing, is washed out without having time to react with the soil.

The most effective in irrigation conditions is three-tiered plowing to a depth of 40 cm, which ensures the destruction of the salt horizon and the mobilization of gypsum reserves available in soils.

The agrobiological method of reclamation also includes measures aimed at increasing the amount of organic substances and enhancing the activity of biological reactions that contribute to the acceleration of reclamation processes in the soil. This is achieved by maintaining an optimal irrigation regime and sowing cultivators. An important role in this method is given to the system of application of organic and mineral fertilizers.

The complex method of reclamation of salt pans includes deep reclamation plowing in order to mobilize calcium salts of the soil and additional application of chemical meliorants. This method of reclamation can be recommended primarily on high-gypsum sulfate-chloride chloride-sulfate and sulfate salt wells, in which gypsum reserves in a layer of 0-40 cm are insufficient to displace exchangeable sodium from the salt horizon.

The calculation of the dose of chemical meliorant for reclamation of high-gypsum salt pans is carried out according to the formula (1), minus the gypsum reserves available in the reclaimed soil layer.

The use of reserves of calcium carbonate of the soil in the complex reclamation of gypsum-free and deep gypsum salt pans is possible provided that after reclamation plowing preliminary washings with the introduction of chemical meliorants are carried out. Such washings should ensure the removal of neutral sols from the soil, including secondary ones, most of the alkaline products of metabolic reactions.

With a complex method of reclamation of deep gypsum and gypsum-free carbonate salt salts, preference should be given to acidic meliorants, including dilute mineral acids.

The rest of the measures that ensure an increase in the fertility of the soils of the salt complex with this method of developing salt deposits are the same as with agrobiological reclamation.

3 Results and discussion

In the presence of soda in the soil, the effectiveness of "neutral" ameliorants (gypsum, clay gypsum) decreases. Acidic ameliorants - phosphogypsum, mineral acids and acidic industrial waste should be used. Phosphogypsum consists of 90% gypsum and contains about 4% of total phosphorus, including 1% water-soluble.

The dose of gypsum or phosphogypsum for alkaline saline soils is determined by the formula 5 proposed by Bobkov V.P.

$$G = 0{,}086 \cdot \{(\mathrm{Na} - 0{,}05 \cdot E) + (S - M)\} \cdot h \cdot \vartheta \tag{5}$$

where S - is the amount of mg/eq. $HCO_3 + CO_3$ contained in the aqueous extract;

M - is the sum of Ca + Mg in an aqueous extract (mg-eq., per 100 g of soil) contained;

To calculate the doses of chemmeliorants containing less than 100% of the active substance, the following formula is used (6).

$$DM = \frac{B \cdot \{(Na - 0{,}05 \cdot E) + (S - M)\} \cdot h \cdot \vartheta}{P} \quad (6)$$

where DM - is the dose of chemmeliorants, t/ha;

B - the amount of the applied chemmeliorant in grams corresponding to 1 mg-eq;

P - is the percentage of the chemmeliorant.

With a salt content of more than 25%, the area of the entire site is reclaimed, phosphogypsum is first applied to the spots of 1/2-3/4 of the dose, and then the rest of the dose is applied to the entire area.

Phosphogypsum can be applied throughout the spring-summer-autumn period, when soil moisture allows for its processing and does not interfere with the movement of agricultural machinery. Immediately after its spreading, the field is disked (preferably in two passes), and then watered taking into account the moistening of at least a 30-centimeter topsoil.

When physical ripeness is reached, it is necessary to plow to a depth of 25-27 cm without preploughs. In irrigation systems where the land has undergone secondary salinization and alkalinization due to the formation of normal and bicarbonate soda, acidic ameliorants will also be required to improve soils, primarily phosphogypsum, a weak solution (sulfuric acid or gypsum (clay gypsum) in combination with dilute mineral acids, which neutralize the soda present in the soil and increase the solubility of chemical meliorants. As a meliorant, a terricon rock with an acidic reaction can also be used.

The dose of chemical meliorant is calculated for the active soil layer of 0.7 - 1.0 m.

4 Conclusion

To substantiate the methods of reclamation of salt pans in irrigation conditions, the following materials are needed:

- soil reclamation map scale 1:25000 or 1:10000;
- map of soil salinization by depth intervals 0-25, 25-50, 50-75, 75-100, 100-150, 150-200 see;
- cartogram of solonets on a scale of 1:10000 or 1:5000 (compiled to substantiate working drawings);
- data on the composition of absorbed cations, the content of gypsum and carbonates in the soils of salt complexes for a layer of 0-75 cm, and on reference sections up to a depth of 1.5 - 2.0 m;
- forecast of changes in the geochemistry of salts and the composition of exchange cations in soils under the influence of irrigation based on natural analogues, experimental washings or routine observations.

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