Emerging Technologies for Recultivation of Disturbed Sandy Soil after Anthropogenic Disturbances in the Industrial Development of the Far North

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Abstract. It was established that the mashed soils in the tundra zone have a light granulometric composition. The humus content in the washed soils of Bovanenkovo gas field does not exceed 0.8%. The humus content in the soil of the sand pit is even less – only 0.1%. Disturbed soils have low reserves of gross and mobile nitrogen, phosphorus and potassium, without additional application of which it is impossible to grow perennial grasses. An effective method of increasing the content of substances in the soil is the application of high standards of mineral fertilizers (N150P150K150). Ammonia nitrogen at low temperature is better absorbed than nitrate nitrogen. The use of peat biomes in combination with mineral fertilizers (N160P160K160) increases the content of nitrate nitrogen in the root layer of the soil 6.3 times, available phosphorus - 1.7 times, potassium - 3.7 times. Nitrate nitrogen is mainly accumulated in the layer where peat was introduced. Introduction to the sandy soil of 4-12 t/ha substrate of BIONE increases the amount of nitrate nitrogen 3.4-5.8 times, available phosphorus - 1.4-1.8 times, mobile potassium –3-4.1 times. Conditions of water and temperature regimes of disturbed soils of the far North and poverty in nutrients necessitate the application of multicomponent mixtures. Technologies of restoration of disturbed sandy soils after their technogenic disturbance in industrial development of the Far North are offered.

1. Introduction

Industrial development of oil and gas fields of the Far North, the construction of new roads and Railways increase the number of man-made disturbed lands. As a result of the activities of the oil and gas industry, there is the formation of territories, which are lifeless sand and desert substrates [1].

The issue of increasing the area of disturbed lands is particularly acute on the Yamal Peninsula. There are a huge number of quarries, because sand is the main material for the construction of sites for the drilling construction of buildings, roads, pipelines and other various structures. According to the Federal registration service as of January 1, 2016, the area of disturbed lands amounted to 1037 thousand hectares, which is 20.8 thousand hectares less as compared to the previous year. The largest areas of disturbed lands in 2015 are located on the territory of Yamal-Nenets Autonomous District – 105.5 thousand hectares (in 2014 – 133.8 thousand hectares) [4].

It is known that the natural systems of the North are characterized by increased vulnerability and fragility caused by instability of permafrost rocks, sharp fluctuations in the parameters of abiotic conditions, comparative simplicity of the structure and relatively low species diversity of plant

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communities [2, 3, 5]. Man-made violations of the surface of the territory of permafrost soils lead to increased cryogenic and other geological processes that change the landscape in an undesirable direction [6].

There are few production experiments on biological reclamation of disturbed lands of the Far North. There is no required number of evidence-based recommendations on the core elements of the biological reclamation techniques, which explains the low effectiveness of the actions taken [7, 8]. In this regard, the development of technologies for the creation of biologically active and sustainable soil and vegetation cover in the Far North, ensuring the stabilization of cryogenic processes in quarries, is of great importance [9, 10].

2. Subjects and Methods

The experimental work was carried out at the alluvial soil quarry of 3-year production of Bovanenkovo gas field and at the bottom of the sand quarry of 15-year production located 15 km from Salekhard. To perform the tasks, we have laid down 2-field experience at each site.

In the experiments, multicomponent mixture were grown: Festuca rubra – 40%; Bromopsis inermis – 35%; Festuca pratensis – 10%, Phleum pratense – 5%; Elytrigia repens – 5%; Poa pratensis – 3%; Beckmannia eruciformis – 2%.

Climatic features of the Far North are due to geographical location. The average annual temperature in the forest-tundra zone is -7^{0}C, in a zone of the tundra is -5^{0}C. The sum of effective temperatures in the forest-tundra zone (above +5^{0}C) is 1100-1200^{0}C (90 days) in a zone of the tundra – 700-900^{0}C (70 days). Precipitation falls are 220-400 mm per year, of which 60% - in spring and summer. Soil temperature at a depth of 10 cm of the warmest month does not exceed +15^{0}C. At a depth of 50-200 cm, the soil is underlain by permafrost.

According to the approved methods, the smallest moisture capacity, volume mass, chemical composition, the content of mineral (ammonia and nitrate) nitrogen, phosphorus and potassium were determined. The depth of soil thawing was determined. Phenological observations of growth and development of perennial grasses were carried out.

3. Results

Our results showed that the content of humus in soils BGF on the control plots is very low. Mineral fertilizers increased the content of humus with all the options. Upon application of NPK at 90 kg/ha on average over three years, the number has increased by 0.06%, $N_{150}P_{150}K_{150}$ – on 0.12%, $N_{210}P_{210}K_{210}$ – on 0.21%. The maximum difference in the content of humus (0.1-0.23%) for the options of experience established for the fourth year of perennial grasses. This fact is explained by slow decomposition of phytomass of perennial grasses at low temperatures of air and soil. The relationship between fertilizer application rate and humus content in 0.3 m soil layer was confirmed by correlation coefficient, which was in 2008 – r = 0.70, 2009 – r = 0.79, 2010 – r = 0.96. It should be noted that the change of humus content occurred almost exclusively in 0.2 m soil layer. In this layer, as studies have shown, about 80% of the mass of roots of perennial grasses is concentrated. The plot's experience, where the seeding of perennial grasses were studied, agrochemical properties of soils remained practically unchanged, including the humus content.

Exchange acidity of soil significantly increased as a result of application of high norms of mineral fertilizers. The most significant acidification around the 0.3 m layer occurred on the background $N_{210}P_{210}K_{210}$. Compared with uncomfortable plots, on average, the exchange acidity increased by 0.5 pH units over three years. The maximum differences (0.7 pH units) were established in the first year after fertilization. In subsequent years, the difference in acidity decreased almost 2 times and did not exceed 0.3-0.4 pH units. The mechanism of acidification of the soil at low temperatures can be partly explained by the fact that with a decrease in temperature absorption of cations increases relatively, and the absorption of anions decreases. In addition, ammonia nitrogen is better absorbed at low temperatures.

It is important to note that alluvial soils used in the development of oil and gas fields of the Yamal Peninsula are close to neutral reaction of the environment. The determination of hydrolytic acidity over four years has allowed us to conclude that it is of low importance.

As a result of the conducted researches, we established low content of nitrate nitrogen in all variants of the experiment (Fig. 1).

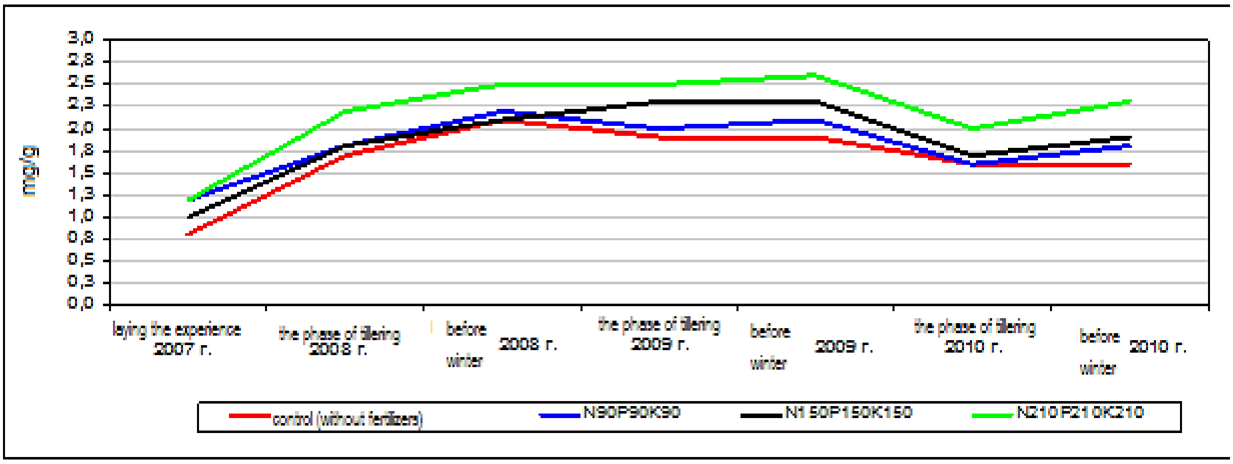

Figure 1. The content of nitrate nitrogen in 0.3 m soil layer BGF with mineral fertilizers, mg/kg

The content of nitrate nitrogen without fertilizer fluctuated during the vegetation period significantly. During all periods of determination for the maximum content of nitrate nitrogen in the control plots observed at a depth of 20-30 cm. All this indicates the migration of nitrate nitrogen in the lungs by granulometric composition of soils. In addition, the movement of nitrates down the profile due to the low buffer capacity of soils due to insufficient humus content. There is a tendency of decrease of nitrate nitrogen content for the fourth year of perennial grasses life.

Mineral fertilization increases the content of ammonium nitrogen in the 0.3 m layer compared with the control 12.5% ($N_{90}P_{90}K_{90}$), 56.2 % ($N_{150}P_{150}K_{150}$), 62.5% ($N_{210}P_{210}K_{210}$). Nitrogen fertilizers are the main source of nitrogen for perennial grasses during reclamation of washed soils.

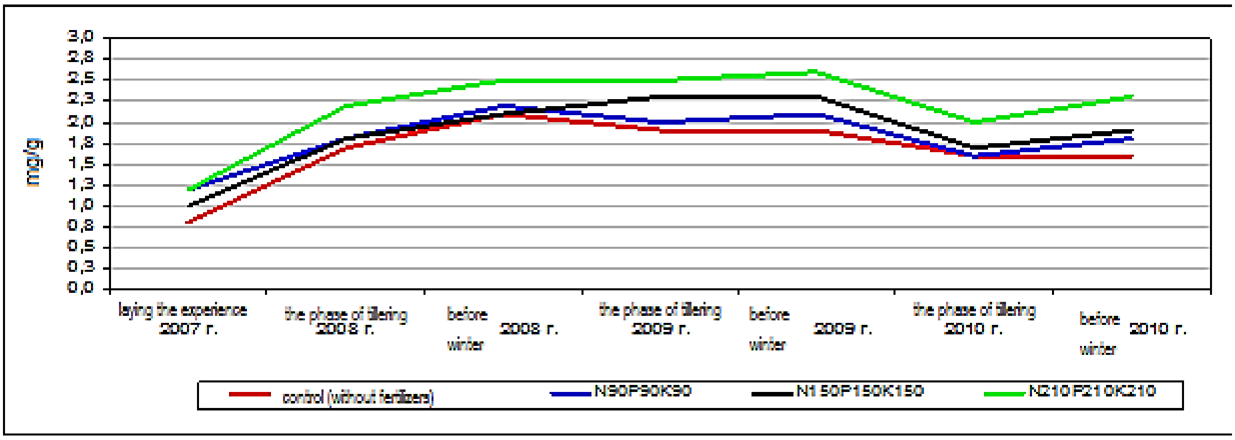

Figure 2. The content of mobile phosphorus in the 0.3 m soil layer BGF with mineral fertilizers, mg/100 g of soil.

Application of mineral fertilizers provided an increase in the content of mobile phosphorus in average three years of research compared to control by 14.3% ($N_{90}P_{90}K_{90}$), 28.5% ($N_{150}P_{150}K_{150}$), 35.7% ($N_{210}P_{210}K_{210}$) (Fig. 2). Between the content of mobile phosphorus and the norms of mineral fertilizers, a close relationship is established, expressed by correlation coefficients from r = 0.95 to r =

0.99. By the end of the growing season of perennial grasses of the fourth year of life, the tendency to a decrease of mobile phosphorus content on all variants of experience, especially where high norms of fertilizers were brought, is traced.

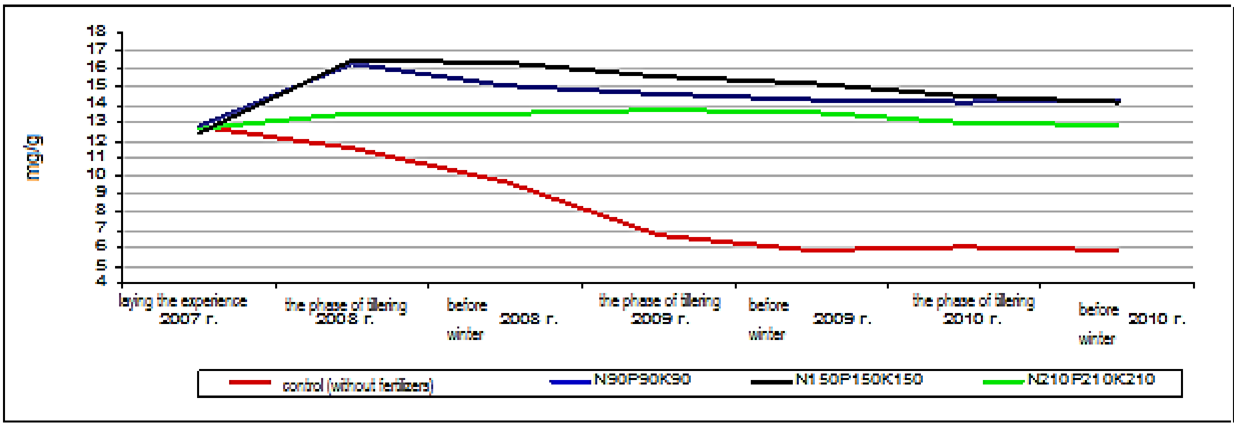

Figure 3. The content of mobile potassium in 0.3 m soil layer BGF with mineral fertilizers, mg/100 g of soil.

BGF reclaimed that soils contain relatively large reserves of total potassium (0.42-0.54%). On average, for three years of research on uncomfortable plots, its content in 0.3 m layer was 7.6 mg/100 g (Fig. 3). It is important to note that the reserves of mobile potassium in the control plots by the end of the vegetation of perennial grasses 4 years of life decreased from 12.8 to 7.6 mg /100 g. The minimum amount of potassium is in the layer 0-10 cm-5.1 mg/100 g, due to its consumption by herbs (Fig. 6). Analysis of the obtained data shows that potash fertilizers have a positive impact on its content in soils. Application of NPK by 90 kg DV / ha increase the content of mobile potassium for an average of three years in 0.3 m layer from 7.6 to 13.4 mg (76.3%), $N_{150}P_{150}K_{150}$ – to 14.8 mg (94.7%), $N_{210}P_{210}K_{210}$ – to 15.4 mg/100 g (102.6%).

Soil sand pit 15 years of development, as noted earlier, have a very low humus content. Its initial quantity from depth more than one meter does not exceed 0.1-0.2%. Therefore, the technology of biological reclamation should include the introduction of organic fertilizers.

As a result of the use of peat biomes (BMT) in combination with mineral fertilizers, the humus content in 0.2 m layer increased over three years, compared to the control, from 0.2 to 0.6% (300%). The use of mineral fertilizers in its pure form also provided a good result. The amount of humus increased twice in comparison with the control. It should be noted that the fertilized BMT variant humus content increases in a short time. When applying only mineral fertilizers, its amount increases at a lower rate, which is understandable. Unlike peat-fertilized dividers, against the background of mineral fertilizers, the amount of humus increases almost only in the layer of 0.1 m. The dependence between mineral fertilizers, peat biomes and humus content of 0.3 m soil layer was confirmed by correlation coefficient, which was in 2009 - r = 0.87, 2010 - r = 0.72.

The soil of the sand pit has a slightly acidic reaction of the soil solution. On the control plots in 0.3 m layer is set to a low value of hydrolytic acidity in all the years of research. Application of mineral fertilizers in pure form and together with peat biomes contributes to increase of hydrolytic acidity.

The results of agrochemical analysis show that the soils of the sand pit contain very few mobile forms of mineral nitrogen. Application of a high norm ($N_{160}P_{160}K_{160}$) of mineral fertilizers has led to a significant increase in the amount of nitrate nitrogen in the upper 0.3 m layer of soil. Its content increased on average by the terms of determination for three years from 0.16 to 0.31 mg/kg, so almost twice. The maximum amount of nitrate nitrogen was contained in plots where peat biomes were used in combination with mineral fertilizers. Here the average for all terms in the 0.3 m layer contained nitrate 1.0 mg/kg, which is higher than the control 6.3 times (Fig. 4). Between the content of nitrate nitrogen in the 0.3 m layer of soil and mineral fertilizers, peat biomes have a relationship, expressed in correlation coefficients from r = 0.58 to r = 0.65.

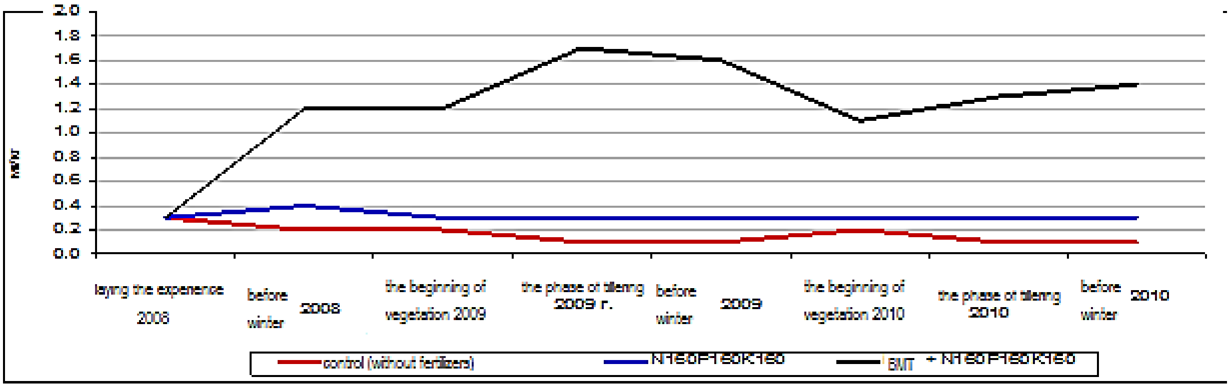

Figure 4. The content of nitrate nitrogen in the 0.3 m soil layer of the sand pit with mineral fertilizers and application of peat BMT, mg/kg

Throughout the years of research at the end of the growing season, there was a very low content of ammonia nitrogen. The content of ammonium nitrogen increased up to 0.04-0.05 mg/kg for mineral fertilizers. The use of peat BMT in combination with mineral fertilizers ensured the presence in the soil ammonium nitrogen in the amount of 0.06-0.08 mg/kg. In not fertilized plots and mineral fertilizers in pure form, the distribution of ammonium nitrogen in the 0.3 m layer was uniform. The distribution of ammonium nitrogen from 20 to 28.6% more than in the 0.1 m layer when using peat BMT.

Gross reserves of phosphorus in the soil to a depth of 120 cm do not exceed 0.03-0.06%. Down the profile its content increases to 0.3-0.5%, i.e. by almost an order of magnitude. In accordance with the gross reserves, the content of available forms of phosphorus is also changed. The content of available phosphorus in the 0.3 m layer before the experiment was 0.5 mg/100 g of soil. The amount of phosphorus in the 0.1 m layer was 2.5-3 times higher than at a depth of 10-20 and 20-30 cm (Fig. 5).

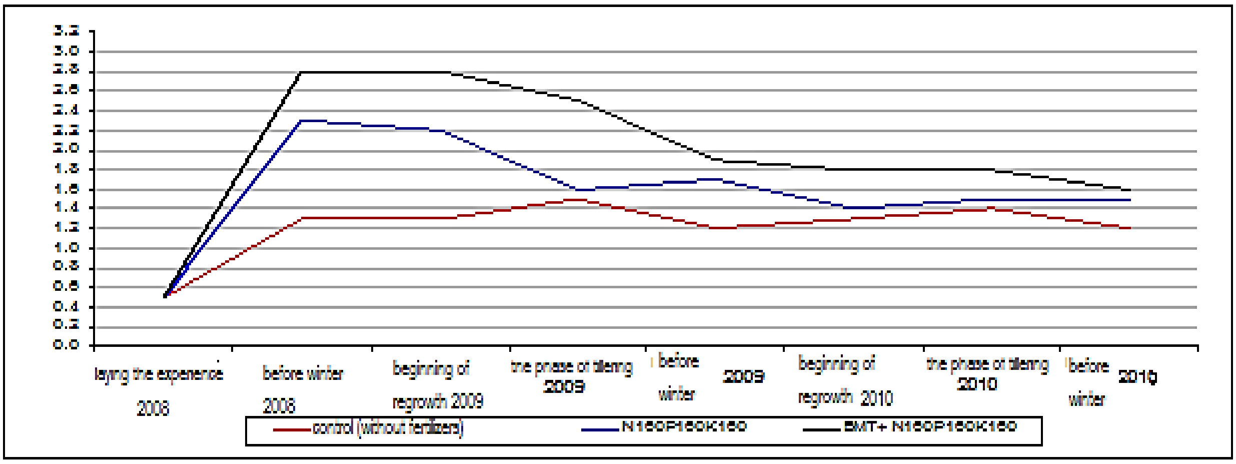

Figure 5. The content of available phosphorus in 0.3 m soil layer of sand pit when applying mineral fertilizers and application of peat biomes

Application of mineral fertilizers increased the content of available phosphorus in a 0.3 m layer on average for three years compared to control from 1.3 to 1.7 mg/100 g of soil (30.8%). The use of peat biomes in combination with mineral fertilizers increased the content of mobile phosphorus in a 0.3 m layer on average for three years from 1.3 to 2.17 mg/100 g of soil (66.9%). Compared with the introduction of mineral fertilizers in its pure form, its content increased from 1.7 to 2.17 mg/100 g of soil (27.6%). This is due to the content of phosphorus in peat, where its amount was 14 mg/100 g of soil. For this reason, the terms determine that the highest amount of phosphorus is installed in the layer of 0-10 cm, i.e. where there has been peat. In the content of available phosphorus in a 0.3 m soil layer and mineral fertilizers, peat biomes, there is a close relationship, expressed correlation coefficients from r = 0.58 to r = 0.97. Therefore, mineral fertilizers and peat biomes play a crucial role in providing perennial grasses with available phosphorus.

Before laying the experiment, the content of mobile potassium in the layer of 0.3 m was 3.0 mg/100 g of soil. The growth and development of perennial grasses were observed in the control plots; the amount was reduced almost twofold (Fig. 6).

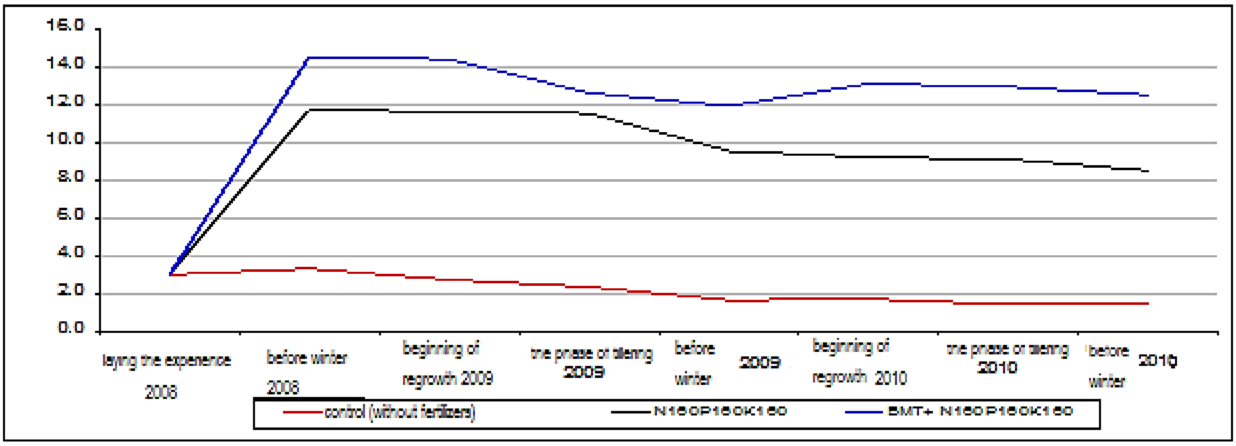

Figure 6. Content of mobile potassium in 0,3 m soil layer of sand pit when applying mineral fertilizers and application of peat biomes, mg/100 g soil

The use of peat biomes in conjunction with mineral fertilizers has further increased the content of mobile potassium throughout the 0.5 meter layer of soil. If when applying $N_{160}P_{160}K_{160}$ on average of three years the amount of mobile potassium was 9.7 mg/100 g of soil, then using BMT in combination with fertilizers its content increased to 11.1 mg/100 g of soil (14.2%). The main part (61%) of potassium is concentrated in a 0.3 m layer. The main part of the potassium in the peat is in the mobile form. Between the content of mobile potassium in the 0.3 m soil layer and mineral fertilizers, peat biomes, there is a very close relationship, expressed correlation coefficients from r = 0.94 to r = 0.97.

Studies have found an increase in humus content, especially when applying the substrate of the BION in the amount of 12 t/ha. Three years after the introduction of the substrate, humus content increased in the 0.3 m soil layer from 0.1 to 0.5% (4 t/ha), 0.9% (12 t/ha). It should be noted that the increase in humus is established throughout a 0.3 m layer. As a result of application of the BION ion-exchange substrate, the amount of the exchange hydrolytic acidity of the soil has not changed. At the same level, the amount of exchange grounds has practically remained.

The use of the BION substrate had a significant impact on the content of mobile forms of nutrients in sandy soil. Without fertilizers, the content of nitrate nitrogen was very low (0.1-0.3 mg/kg) throughout all years of the study. During the growing season its quantity practically did not change. The entry of the substrate of BION in the amount of 4 t/ha increased the content of nitrate nitrogen in the 0.3 m layer of soil compared with the control on average for three years from 0.15 mg to 0.51 mg/kg (340%). The increase in the norm of the BION substrate to 6 t/ha led to an increase in nitrates to 0.72 mg/kg (480%), 12 t/ha – to 0.88% (587%). There is a very close connection between the content of nitrate nitrogen in 0.3 m of the soil layer and the norms of the BION substrate, expressed by correlation coefficients from r = 0.91 to r = 0.99.

4. Conclusion

1. The humus content in the washed soils of Bovanenkovo gas field does not exceed 0.8%. The humus content in the soil of the sand pit is even less – only 0.1%. The amount of humus in the soil of the sand pit from making $N_{160}P_{160}K_{160}$ increases over three years to 0.3%. Accumulation of humus under the influence of fertilizers occurs only in a 0.2 m layer of soil. The use of peat biomes increases humus content in a 0.1 m layer to 0.9%. Adding to the sandy ion-exchange substrate of the BION increases the amount of humus in a 0.3 m layer.

2. The studied soils of BGF have low reserves of gross and mobile nitrogen forms (0.04-0.06% and 1.8-2.2 mg/kg NO_3, 0.81-1.42 NH_4), phosphorus (0.071-0.085% and 0.11-0.12 mg/100 g of soil) and potassium (0.42-0.54% and 1.26-1.28 mg/100 g of soil), without additional application of which it is impossible to grow perennial grasses. The use of peat biomes in combination with mineral fertilizers ($N_{160}P_{160}K_{160}$) increases the content of nitrate nitrogen in the root layer of the soil 6.3 times, available phosphorus – 1.7 times, potassium – 3.7 times. Nitrate nitrogen is mainly accumulated in the layer where peat was introduced. Introduction to the sandy soil of the 4-12 t / ha substrate of BIONE increases the amount of nitrate nitrogen 3.4-5.8 times, available phosphorus – 1.4-1.8 times, mobile potassium – 3-4.1 times. There is a removal of potassium outside the root zone.

3. The biological reclamation on light of the granulometric structure of soils should be performed using multicomponent mixtures, including the following species: Festuca rubra – 40%; Bromopsis inermis – 35%; Festuca pratensis – 10%, Phleum pratense – 5%; Elytrigia repens – 5%; Poa pratensis – 3%; Beckmannia eruciformis – 2%. With low bushiness of perennial grasses in harsh soil and climatic conditions of the Far North, the optimal density of vegetation is achieved at a rate of seeding of perennial grasses of 120 kg/ha.

4. The creation of stable phytocenoses of perennial grasses in the far North is possible with the use of the ion-exchange substrate of BION (4-6 t/ha), increased doses of mineral fertilizers ($N_{90\text{-}160}P_{90\text{-}160}K_{90\text{-}160}$) in a pure form or in combination with peat biomes in places with a high concentration of surface runoff.

5. Within the limits of a particular career, restoration activities should be of a local-territorial nature. This is due to the volume of the disturbed area, the irregularity of the bottom and slopes of the quarry, the granulometric composition of the soil, the degree of water content, changes in the acidity of the soil with depth.

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