Evaluation of organomineral fertilizer for restoration under the conditions of the Far North of disturbed illuvious-ferruginous podzol

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Abstract. The results of a model experiment on the use of organomineral fertilizer (OMF) based on food waste for the sowing of three mixtures of perennial cereals on a sample of the soil type of the Far North: an illuvial-ferruginous podzol with the aim of developing a technology for the restoration of disturbed soil cover are presented. It was revealed that when OMF is added in the amount of 25 and 50%, the physicochemical properties of the soil improve; there is an increase in the green mass of plants relative to control by an average of 3.3 times. When 50% of this fertilizer is applied, signs of plant inhibition are observed on day 18, which indicates an overabundance of nutrients in the soil. The mass of plants at this concentration is close to the values obtained at 25% OMF content. Organomineral fertilizer based on food waste with the obtained characteristics can be used in the restoration of the illuvial-ferruginous podzol as a reclamation fertilizer.

Keywords: organic-mineral fertilizer, perennial cereals, physicochemical properties of soils.

1. Introduction

In the Far North, the most vulnerable is the land cover - the main structure-forming element of natural landscapes. The presence of permafrost at shallow depth sharply limits the thickness of the biologically active layer, in which nutrients, plant roots, soil microorganisms and animals are concentrated. Destruction, scalping of the surface soil layer leads to the destruction of the vegetation cover, access to the surface of the mineral part of the profile, and, as a result, the development of solifluction processes, erosion, and karst. As a result of the development of mineral deposits, the laying of gas pipelines, roads and other technological disturbances in the Yamalo-Nenets Autonomous Okrug, the area of completely disturbed lands amounts to 377557 hectares, according to other sources, land losses are estimated at 6 million hectares or 8% of the territory [9]. Therefore, there is an acute question of reclamation of disturbed soil cover taking into account bioclimatic conditions. Often, enterprises exploiting natural resources carry out only technical restoration of disturbed territories, considering it acceptable to leave the land for self-growth. The processes of natural restoration of vegetation of technogenic landscapes are complex and time-consuming (up to 30 years) and are complicated by random factors [8].

Bioremediation is now recognized as possibly the most attractive clean-up approach for Polar Regions. Numerous contaminated sites in Polar Regions have legacy contamination that is often
associated with weathered contaminants that tend to be recalcitrant to bioremediation. There is growing interest in cold-region landfarming because it is a relatively inexpensive and effective method for dealing with contaminated soils in inaccessible areas. This technique has proven to be effective in the Arctic. Reports of effective landfarming of higher-molecular weight compounds in cold climates are limited and concerns remain about the effectiveness of this technology [15].

Polar soil environments differ from other soil environments in a number of ways that might affect hydrocarbon biodegradation. Polar soils have unique periglacial features, including permafrost and numerous types of patterns primarily due to freeze-thaw effects. In the Arctic tundra, an active soil zone, above the permafrost, thaws for a period of typically 1±2 months in the summer. Summer temperatures in the active zone are highly dynamic and vary greatly, from near freezing at the permafrost interface to occasionally above 20°C at the surface. Permafrost restricts water movement and sometimes results in a saturated active zone. The active zone is where most hydrocarbon contaminants exist and is presumably the site of most biological activity. Little is known about the relationships between permafrost and hydrocarbon contaminants. Many Arctic tundra soils are low in organic content, a characteristic which can be expected to directly affect sorption of hydrocarbons to the soil and to indirectly affect biodegradation of hydrocarbons. Arctic tundra soil microbial communities have not been well characterized. There is presently no convincing evidence that the composition or structure of these communities is unique to Arctic tundra; although, the biomass may be low and the organisms more cold-adapted, relative to soils in temperate regions. Organic decomposition is slow in Arctic tundra soils, largely due to low temperatures. Some studies indicate the presence of hydrocarbon-degrading microorganisms in Arctic tundra soils and groundwater. Similarly, hydrocarbon-degrading microorganisms have been reported in Antarctic soils. Physical, chemical and biological factors have complex effects on hydrocarbon biodegradation in soil. For this reason, experts frequently recommend that soil bioremediation projects begin with treatability studies to empirically test the biodegradability of the hydrocarbon contaminants and to optimize treatment conditions. On the other hand, it is possible that the expense of such treatability studies could be avoided or minimized, if certain soil characteristics could be measured and used to predict the potential for bioremediation of a site, the kinetics of hydrocarbon removal or the optimal values for certain controllable treatment conditions. For example, certain co-contaminants such as heavy metals might preclude hydrocarbon bioremediation. Or, soil particle size distribution might partly dictate the potential rate and extent of hydrocarbon removal [16].

Measures to restore the disturbed lands of the Far North should be aimed at creating a fertile layer and selecting affordable mixtures of perennial grasses adapted to specific environmental conditions that can form a stable grass and turf in a short time [3, 6, 7]. Creating a stable turf cover is difficult without additional application of organomineral substrates - peat, land, manure, mineral fertilizers [4]. The best results of restoration of tundra soil are given by the combined use of mineral and organic fertilizers [11]. In the case of reclamation of sandy soils, the best result also comes from the integrated use of mineral fertilizers with peat [12]. The introduction of peat is complicated by the fact that it is necessary to develop it, and this is a violation of the soil cover with a subsequent set of measures for its restoration. As an alternative, technologies are proposed for the use of potassium humate preparations, which can be used as a stimulator of the growth and development of perennial grasses sown on disturbed tundra soils for the purpose of their reclamation [13].

In addition to man-made disruptions of natural ecosystems, the amount of human waste around human settlements is growing. Their disposal is an important problem that must be solved in parallel with the restoration of technogenic landscapes. For various remediation purposes, various types of waste can be used. In proceedings [14], the possibility of using organic waste (excess activated sludge, sedimentary brewer’s yeast, chitosan) from the Murmansk region for the restoration of oil-contaminated podzol soils. Comparison of indicators of the content of oil products in soil samples with indicators of phytotesting on plant seedlings allowed us to conclude that it is advisable to use the tested waste as reclamants of oil-contaminated soils.
One of the promising directions for solving the problem of organic fertilizer and at the same time solving the problem of waste from settlements is the processing of food waste into composts. An approach to soil disinfection and restoration using plants, mushrooms and composts, without the use of synthetic fertilizers, is promising for reclamation in facilities with a cold climate [15].

In the Far North, composting in an open way is inefficient, due to low temperatures, a short period of positive temperatures. At the same time, if there is an isolated base and a greenhouse structure, it becomes possible to protect the substrate from climatic factors. A technology has been developed to produce environmentally friendly organic-mineral fertilizer based on food waste directly within the places of their formation and accumulation.

The use of this technology will help to improve the environmental situation by eliminating stored food waste and reducing the cost of biological reclamation of land in adjacent territories.

The aim of this work is to evaluate the effectiveness of the application of organic fertilizer based on food waste when sowing various mixtures of perennial cereals to restore disturbed soil cover in the Far North.

2. Object and methods

The experiment was conducted in laboratory conditions with soil sampled in the Novy Urengoy district of the Yamalo-Nenets Autonomous Okrug. The soil was used from a depth of 5-30 cm, as these horizons go to the day surface because of an intense anthropogenic load.

The soil is an illuvial-ferruginous podzol, and horizon A₂ is a grayish-whitish fine-grained sand. [5].

Organomineral fertilizer (OMF), obtained by solid-phase fermentation from food waste from the village of Yubileiny, Yamalo-Nenets Autonomous Okrug. In the process of fermentation, lime was introduced into the composition to form the fertilizer structure and deoxidize the substrate.

The physicochemical analysis showed that OMF has an alkaline reaction (Table 1), according to the grouping of soils by nitrifying ability, the content of mobile phosphorus, exchange potassium and humus belong to a very high class of security. Moreover, all of the above indicators (except for humus, the excess of which within the limits of this class) are exceeded several times [1], which confirms its high agrochemical effectiveness.

The soil is characterized by a neutral aqueous pH, a very low content of organic matter, and a low content of alphitite (Table 1).

### Table 1. Chemical and physical properties of soils, soil mixtures and organomineral fertilizers (OMF)

| Measured indicators                  | Podzol illuvial-ferruginous | Soil mix with organomineral fertilizer (25%) | Organomineral fertilizer |
|-------------------------------------|-------------------------------|---------------------------------------------|--------------------------|
| pH, aqueous extract                 | 7,0                           | 8,7                                         | 8,7                      |
| pH, salt extract                    | 5,4                           | 8,3                                         | 8,2                      |
| Organic matter, %                   | 0,2                           | 2,7                                         | 10,6                     |
| N-NH₄, mg/kg                       | 11,9                          | 342,5                                       | 1977,8                   |
| N-NO₃, mg/kg                       | 1,7                           | 86,2                                        | 112,8                    |
| P₂O₅, mg/kg                        | 12                            | 55                                          | 430                      |
| K₂O, mg/kg                         | 3                             | 1963                                        | 8062                     |
| Alphitite content (<0,01 mm), %    | 6,9, (cohesive sand)          | 7,8 (cohesive sand)                         | 19,8 (clayed sand)       |

A mixture of soil with organic fertilizer was prepared in a ratio of 3: 1 (75: 25%) and 1: 1 (50:50%) by dry weight. The physicochemical properties of the obtained substrate were determined.

For analysis, samples were prepared with one dose of application - 25% by dry weight, which allows you to recalculate the result of application for any dose.
After the addition of 25% OMF, the chemical characteristics of the soil mixture improved according to the content of nutrients (NPK) and organic matter (Table 1).

To conduct a model experiment, soil samples of the illusionally-glandular soil podzol and soil-mixture with a OMF content of 25 and 50% were placed in plastic vessels, according to the principle of Mitcherlich’s vessels, with openings on the bottom and trays for collecting water. The surface area of the vessel is 95 cm². After filling the vessels, the humidity of the mixtures in all cases was brought to the ultimate field water capacity and maintained at this level during the growing of plants. The experiment was carried out in triplicate.

In all vessels with organic soil-samples carried crop of 0.5 g three gramineous grass mixtures. 

**Mix No. 1:** perennial ryegrass (*Lolium perenne*) - 25%; red fescue (*Festuca rubra*) - 47%; meadow bluegrass (*Poa pratensis*) - 13%; creeping bent (*Agróstis stolonífera*) - 15%.

**Mix No. 2:** red fescue altered (*Festuca rubra commutata*) - 15%; red fescue (*Festuca rubra*) - 35%; meadow bluegrass (*Poa pratensis*) - 10%; sheep fescue (*Festuca ovina*) - 5%; perennial ryegrass (*Lolium perenne*) - 35%.

**Mix No. 3:** couch grass (*Elytrígia répens*) - 20%; meadow fescue (*Festuca pratensis*) - 60%; perennial ryegrass (*Lolium perenne*) - 20%.

The selection of these perennial cereals is based on literature data [2,9]. Basically, the mixtures are represented by grassroots perennial cereals that are most stable in the Far North and are capable of reproduction.

Similar cereal mixtures were seeded into control soil samples. Tanks with crops were covered with glass and placed in a greenhouse.

Thus, for each soil sample, nine experimental variants were obtained: three - with sowing of three mixtures of herbs in control samples; three - a mixture with the introduction of 25% OMF and sowing herbs, as well as with the introduction of 50% OMF.

The experimental conditions are the greenhouse of the greenhouse, which eliminates accidental effects on the growth and development of plants.

Duration of illumination is 12 hours a day, 12 hours a night, illumination 25000 lm/m², temperature + 20 ± 2°C, air humidity 60 ± 5%.

After emergence (on the third day), the coverslips were removed. Irrigation was carried out every three days with distilled water with a pH of 6.3, at the same time the height of the plants (maximum, average, minimum) was measured in all variants of the experiment.

This is due to the fact that mixtures of herbs were sown, the seeds of which have different sizes, different rates of germination and differ in productivity (mass of one plant).

The time of the vegetation experiment is 21 days after germination. Further, in all variants of the experiment, the weight of the green mass in the wet and dried state was evaluated, and a comparison was made relative to the control.

### 3. Results and discussion

During the experiment, it was noted that during the entire time in the control samples of the lluvial-ferruginous podzol, there was a lag in the formation of the green mass of plants in comparison with all variants of the experiment, which is associated with the physicochemical properties of this soil. In the variant containing 50% organic fertilizer, more intensive plant growth was observed, but on the 18th day the tips of the leaves began to dry and darken, which indicates an excessive content of nutrients when using such a dose of fertilizer, which leads to growth inhibition.

Table No. 2 presents data on the average weight (in three replicates) of the top mass of plants according to 9 experimental variants. In the control, the moisture content of plant samples was 72-73%, with the addition of 25 and 50% OMF, the humidity increased to 86%. Regarding control, the weight of the top parts of plants in the wet state increased more than three times, in the dried state - more than 1.5 times. For a grass mixture consisting of *Lolium perenne*, *Festuca rubra*, *Poa pratensis*; *Agróstis stolonífera*, the yield increase was maximum in both wet and dried state. With the introduction of 50% OMF into the soil, the weight of the green mass of plants slightly decreased for
all variants with respect to the fertilizer dose of 25%, which confirms the fact of inhibition of plant development due to an excess of nutrients.

Table 2. The mass of plants grown in illuvial-ferruginous podzol

| Variant     | Grass mixture | Green mass weight (g) | The increase in control, % | The weight of the dried green mass (g) | The increase in control, % |
|-------------|---------------|-----------------------|----------------------------|----------------------------------------|----------------------------|
| Control     | 1             | 0,52±0,02             |                            | 0,140±0,002                            |                            |
| Control     | 2             | 0,51±0,02             |                            | 0,139±0,002                            |                            |
| Control     | 3             | 0,49±0,02             |                            | 0,138±0,002                            |                            |
| Soil + 25% OMF | 1    | 1,85±0,25             | 256                        | 0,258±0,002                            | 84                         |
| Soil + 50% OMF | 1    | 1,80±0,02             | 246                        | 0,250±0,002                            | 79                         |
| Soil + 25% OMF | 2    | 1,65±0,05             | 224                        | 0,230±0,005                            | 65                         |
| Soil + 50% OMF | 2    | 1,58±0,05             | 210                        | 0,230±0,005                            | 65                         |
| Soil + 25% OMF | 3    | 1,70±0,05             | 247                        | 0,240±0,005                            | 74                         |
| Soil + 50% OMF | 3    | 1,63±0,05             | 233                        | 0,238±0,005                            | 72                         |

4. Conclusions

During the experiment, it was found that organomineral fertilizer, based on food waste, is characterized by a high content of nutrients NPK, which confirms its high agrochemical effectiveness. OMF improves the physicochemical properties of the illuvial-ferruginous podzol. No drying of the soil surface is observed, and optimal conditions are created for plants to consume available moisture and nutrients.

At 50% content of OMF by external signs, inhibition of plants is observed on the 18th day of the experiment, which indicates an excessive content of nutrients. Therefore, the use of this dose is not recommended.

The introduction of OMF in the amount of 25 and 50% leads to an increase in the yield of the presented mixtures of herbs relative to the control by an average of 3.3 times.

For illuvial-ferruginous podzol in control and variants OMF best results are obtained for the second mixture of cereals: perennial ryegrass (*Lolium perenne*) - 25%; red fescue (*Festuca rubra*) - 47%; meadow bluegrass (*Poa pratensis*) - 13%; creeping bent (*Agróstis stolonífera*) - 15%.

Organomineral composition based on food waste, with the obtained characteristics, is suitable for use in the restoration of the disturbed illuvial-ferruginous podzol as a complex organic fertilizer and ameliorant in the Far North.

References

[1] Agrochemical examination and monitoring of soil fertility: a training manual. Stavropol: AGRUS, 2012, 352 p.

[2] Biological reclamation of disturbed lands in the Yamal Peninsula: Recommendations. - Novosibirsk, 1994, - 48 p.
[3] Likhanov A. I., Archegova I. B. Development of theoretical and practical aspects of the restoration process of disturbed lands in the north of the Komi Republic // Theoretical and Applied Ecology. 2014. No3. pp. 79-85

[4] Nazarova G.V., Ivanov V.V., Gavril’yeva L.D., Mironova S.I. On the issue of using waste in the restoration of disturbed lands // Successes in modern natural science. - 2012.-No 11. pp.135-136.

[5] National Atlas of Soils of the Russian Federation / Under the General Ed. corresponding member RAS S.A.Shoba. Faculty of Soil Science, Moscow State University M.V. Lomonosov. - M.: Astrel Publishing House, 2011, pp. 500-502.

[6] Popov A.I., Kapelkina L.P. Restoration of vegetation on disturbed lands in the Nenets Autonomous Okrug // Plant Resources, - 2012.- V. 4. No. 2.- pp. 278-287.

[7] Pystina N. B., Baranov A.V., Listov E.L., Budnikov B.O. Improvement of technologies for the restoration of disturbed and contaminated lands in hydrocarbon deposits of the Far North. // Scientific Bulletin of the Yamal-Nenets Autonomous Okrug. - 2016.- No: 2 (91). pp. 4-8.

[8] Sumina O.I., Koptseva E.M. On the classification of technogenic vegetation in the Far North of Russia // Collection of the scientific works of GNSS. 2016. V.143. pp. 224-230.

[9] Tikhonovsky A.N. Problems and methods of biological reclamation of technologically disturbed lands of the Far North. // Successes of modern science. - 2017. - No. 2 pp. 43-47.

[10] Korneykova M.V., Myazin, V.A., Fokina, N.V. Restoration of Oil-Contaminated Soils in Mountain Tundra (Murmansk Region, Russia) // Springer Geography. 2020, Pages 187-198

[11] Iglovikov A.V., Motorin A.S. Emerging Technologies for Recultivation of Disturbed Sandy Soil after Anthropogenic Disturbances in the Industrial Development of the Far North // IOP Conference Series: Earth and Environmental Science Volume 194, Issue 9, 15 November 2018, Номер статьи 092009

[12] Galiulin R.V., Bashkin V.N., Galiulina R.A., Alekseev A.K. Potassium humate for the restoration of disturbed tundra soils // Business journal Neftegaz.ru. 2018. - No. 3 (75) - p. 104-106.

[13] Vasilieva Zh.V., Gorbovskaya T.D., Pavlov A.V. Reclamation of oil-contaminated soils using organic waste in the Kola North // Bulletin of the Murmansk State Technical University. 2019.Vol. 22. No.1. pp. 72-82.

[14] Robichaud K., Stewart K., Labrecque M., Hijri M., Chereyk, J., Amyot, M. An ecological microsystem to treat waste oil contaminated soil: Using phyto remediation assisted by fungi and local compost, on a mixed-contaminant site, in a cold climate // Science of the Total Environment Volume 672, 1 July 2019, Pages 732-742

[15] Sanscartier D., Laing T., Reimer K., Zeeb B. 2009. Bioremediation of weathered petroleum hydrocarbon soil contamination in the Canadian High Arctic: Laboratory and field studies. Chemosphere 77:1121-1126.

[16] Mohn, W.W., Stewart, G.R., 2000. Limiting factors for hydrocarbon biodegradation at low temperature in Arctic soils. Soil Biol. Biochem. 32, 1161-1172.