Application studies of organomineral fertilizer for restoration under the conditions of the Far North of disturbed illuvial-ferruginous podbur

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Abstract. The work is devoted to the use of organomineral fertilizer (OMF) based on food waste for sowing three mixtures of perennial cereals and the reclamation of an illuvial-ferruginous podbur in the Far North. Under the conditions of a model experiment, it was found that when OMF is introduced in fractions of 25 and 50%, the physicochemical properties of the soil improve. There is an increase in the green mass of plants relative to the control by 2.3 times. Adding 50% of the presented fertilizer leads to inhibition of cereals. The mass of plantings at this dose of fertilizer approaches the figures appearing in the experiment with 25% OMF. The presented organic-mineral fertilizer based on food waste can be used for the rehabilitation of disturbed soils of the illuvial-ferruginous podbur as fertilizer.

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

1. Introduction

In the Arctic, environmental degradation is taking on dangerous trends. Disturbance and destruction of natural ecosystems causes serious damage. Violation of the fragile Arctic nature may be irreversible. The natural landscapes of the Arctic have lesser stability, self-healing processes are carried out slowly. Anthropogenic impact leads to degradation of the Arctic lands, which in the long run may lead to irreversible environmental processes. Activation of the processes of soil deformation, thermokarst and thermoerosion is manifested especially intensively in the centers of industrial development and along linear structures (oil and gas pipelines, railways and highways, power lines, etc.). The annual growth of uncultivated disturbed lands is: in the oil industry - 5-6 thousand ha, in the gas industry - 2.5-3 thousand hectares, in the construction of pipelines - 0.4-0.5 thousand hectares [10].

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 [12].
Podburs are formed in the flat and mountainous regions of the tundra, northern and middle taiga under conditions of good drainage on stony-fine-grained eluvium-deluvium of extrusive and metamorphic rocks and polymineral sandy - sandy loamy rocks rich in bases and ferruginous primary minerals. The profile of podbur consists of a peaty litter or a humus horizon with rare mineral grains clarified due to the removal of ferruginous films. Below lies an alpha-humus horizon of brown or buffy-brown color, formed as a result of the illuvial accumulation of aluminum-ferrous-humic compounds, the skeleton and grains of fine earth are covered with brown allochthonous films. The horizon brightens down and gradually passes into the parent rock. The substrates are characterized by an acidic and strongly acidic reaction of the entire profile with a decrease in acidity downward, base unsaturation, accumulative distribution of sludge, exchange bases and humus of fulvate composition with a predominance of mobile and aggressive fractions. The distribution of gross and oxalation-soluble forms of Fe and Al oxides is predominantly accumulative [5].

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 [13].

The presence of permafrost limits the development of a biologically active soil layer in the Far North. Due to harsh natural conditions and a very short vegetative period, restoration of the vegetation cover is very slow, also due to the development of solifluction processes and water erosion. As a result, the mining and other human activities inevitably leads to disruption of the soil cover [9]. The effectiveness of restoration of disturbed soil is substantially dependent on climatic conditions and, as a consequence, biological activity. With the natural restoration of soils after anthropogenic impact, the processes take a long time and are complicated by random factors [8].

When restoring disturbed soils in the Arctic conditions, it is supposed to create a fertile layer and sow perennial grasses that can form a stable turf cover [3, 6, 7]. To form this cover, additional resources of organic matter, mineral fertilizers and ameliorants are needed [4]. Moreover, the availability of these resources in the Arctic is limited, mainly due to the remoteness of disturbed objects.
A certain amount of organic waste is produced in settlements. Their processing into organic fertilizers will provide funds for the restoration of disturbed soils. One of the most promising areas of processing large volumes of food and other organic waste is composting, which is a recycling technology based on the biochemical decomposition of the organic fraction. Together with food waste, it is possible to process leaves, branches, mowed grass, waste from biochemical wastewater treatment, etc. To date, composting can be carried out both by private farms and enterprises on an industrial scale. On an industrial scale, composting can be carried out in special storage pits (long compost heaps). The processing technology is extremely simple: layers of food waste are strewn with soil, plant debris and undergo aerobic fermentation. Using high-level technologies, compost can mature in 2-3 weeks. Intensification of the process requires periodic aeration of the storage pits. The composting process is exothermic, a temperature regime from 50 to 70 °C is created inside the processed mass, which provides anthelmintic and antimicrobial action [11].

A technology has been developed for producing organic fertilizer based on food waste by solid-phase fermentation directly at the place of its formation.

Use of this technology can contribute to improving the environmental situation due to the processing of accumulated food waste and reducing the cost of biological reclamation of adjacent territories.

The aim of the work is to predict the possibility of using organomineral fertilizer based on food waste to restore disturbed soil cover using grass mixtures from perennial cereals in the Far North.

2. Objects and methods
The experiment was conducted in laboratory conditions with soil selected in the area of the city of Nadym of the Yamalo-Nenets Autonomous Okrug. The sampling depth is 5-30 cm. Sampling from a given depth is explained by the fact that, in places of intense anthropogenic load, these horizons go to the surface.

The soil is illuvial-ferruginous podzol, the Bh horizon (5-30 cm) is a brownish-yellow loam [5].

Organomineral fertilizer obtained by solid-phase fermentation from food waste from the village of Yubileiny, Yamalo-Nenets Autonomous Okrug. The composition introduced lime for deoxidation of the substrate and the formation of the structure.

Physicochemical analysis of OMF showed that it has an alkaline reaction (Table 1); according to the soil grouping by nitrifying ability, the content of mobile phosphorus, exchange potassium and humus, they belong to a very high class of security. The listed 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.

| Measured indicators           | OMF     | Soil before OMF | After OMF 25% introduction |
|------------------------------|---------|-----------------|---------------------------|
| pH, aqueous extract          | 8,7     | 5,3             | 7,2                       |
| pH, salt extract             | 8,2     | 4,2             | 6,8                       |
| Organic matter, %            | 10,6    | 1,4             | 2,5                       |
| N-NH₄, mg/kg                 | 1977,8  | 16,3            | 359,3                     |
| N-NO₃, mg/kg                 | 112,8   | 5,1             | 63,3                      |
| P₂O₅, mg/kg                  | 430     | 11              | 90                        |
| K₂O, mg/kg                   | 8062    | 548,7           | 3299                      |
| Alphitite content (<0,01 mm), % | 19,8 (sandy loam) | 48,3 (heavy loam) | 52,4 (light clay) |

Mixtures of soil samples with organic fertilizer were prepared in a ratio of 3: 1 (75: 25%) and 1: 1
(50:50%) by dry weight. The determination of physico-chemical properties (Table 1).

Change in chemical parameters was carried out with one dose of application - 25% by dry weight. It was found that the chemical characteristics improved, the reaction of the medium changed from acidic to neutral, the content of nutrients (NPK) and organic matter increased significantly (Table 1).

In order to conduct the experiment, soil samples and mixtures with organic fertilizer content of 25% and 50% were placed in plastic vessels, with holes in the bottom in the shape of Mitchell's vessels and trays for collecting water. The surface area was 95 cm². Soil mixtures in all variants were equalized in moisture to ultimate field water capacity and maintained in such a process during the experiment. Each variant of the experiment was laid out in triplicate.

In each variant, 0.5 g of three cereal mixtures of herbs were sown on a vessel.

**Mix No. 1:** perennial ryegrass (*Lolium perenne*) - 25%; red fescue (*Festuca rubra*) - 47%; meadow bluegrass (*Poa pratensis*) - 13%; creeping bent (*Agróstis stolonifera*) - 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 presented perennial cereals were taken in the experiment based on the literature data and the principles of the availability of seeds and their resistance to adverse conditions of the Far North - frost resistance, resistance to waterlogging, and the ability to reproduce in the short growing season [2,9].

Similar mixtures were seeded in control variants. The containers were covered with glass and placed in a greenhouse.

In total, the experiment included nine variants: three - with the sowing of three mixtures of herbs in the original soil; three - soil with the introduction of 25% OMF with the sowing of herbs, similarly with the introduction of 50% OMF.

The experimental conditions are a greenhouse, which eliminated accidental effects on 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

Throughout the experiment, in variants with control, there was a lag in the increase in the mass of cereal plants, which is associated with the initial physicochemical properties of the soil presented. In all variants with 50% fertilizer, there was a more intensive growth of plants at an early period of time, but by the end of the experiment their indicators were similar. Nevertheless, on day 18, the tips of leaf blades began to dry and blacken, which indicates an excessive concentration of nutrients when a given dose of fertilizer is applied, which leads to inhibition of plant growth.

The maximum yield with the addition of 25 and 50% OMF was noted for grass mixture No 2, consisting of *Festuca rubra commutata, Festuca rubra, Poa pratensis; Festuca ovina; Lolium perenne* (Table 2).

**Table 2.** The mass of plants grown in illuvial-ferruginous podbur
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 0.83±0.02 0.180± 0.002
Control 2 0.84±0.02 0.192± 0.002
Control 3 0.85±0.02 0.188±0.002

soil + 25% OMF 1 1.82±0.02 119 0.258 ± 0.002 43

soil + 50% OMF 1 1.80±0.02 117 0.258 ±0.002 43

soil + 25% OMF 2 2.00±0.12 138 0.275±0.025 43

soil + 50% OMF 2 2.20± 0.15 162 0.275±0.025 43

soil+ 25% OMF 3 1.92±0.015 126 0.270±0.05 44

soil + 50% OMF 3 2.20± 0.15 159 0.268±0.02 43

The green mass of plants in relation to control increased by 2.3 times, and 1.4 times for dry weight. At a 50% content of this fertilizer in the soil mixture, the largest increase in the weight of plants in the wet state is noted. In the dried state, the mass of plant samples is the same for all variants of grass mixtures with fertilizer applied.

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.

Organomineral fertilizer has a positive effect on the physicochemical properties of the pickup, and prevents the drying of the surface soil layer.

When applying of 50% OMF, inhibition of plants is observed on day 18 of the experiment, which indicates an excessive concentration of nutrients.

Adding OMF in fractions of 25 and 50% leads to an increase in the yield of grass mixtures in relation to control by an average of 2.3 times.

During the vegetation of plants for their biomass, the best results were obtained with a mixture of red fescue (*Festuca rubra*) - 35%; perennial ryegrass (*Lolium perenne*) - 35%; altered red fescue (*Festuca rubra commutata*) - 15%; meadow bluegrass (*Poa pratensis*) - 10%; sheep fescue (*Festuca ovina*) - 5%.

The presented organic-mineral fertilizer based on food waste can be used for the rehabilitation of disturbed soils of the illuvial-ferruginous podbur as a fertilizer in the Arctic.

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