Possibility of ecological remediation of oil production territories with the use of industrial hemp

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Abstract. Variants of fulfilling the technologies of phytoremediation are considered, which propose to plant oil-contaminated territories with vegetation with microbial communities in its rhizosphere characterized with high microbial content, and at the same time with high emulsifying properties. A list of plants for phytoremediation is given. In the context of the northern territories of the Irkutsk Region, a possibility to use industrial hemp as a plant for phytoremediation of oil-contaminated soils is demonstrated. The composition of the oil-contaminated soils with regard to the distance from a drilling rig is studied. Depending on the level of contamination, the germinating ability of the industrial hemp seeds is assessed. Keywords: oil-contaminated soils, phytoremediation, germinating ability, industrial hemp

1. Introduction

Production, storage, and transportation of oil, in their total man-caused impact on the environment, belong to one of the aggressive industrial sectors affecting the biosphere objects. The most severe damage is inflicted to the soil in the areas of oil production. As a result of technological operations, oil refinery waste of three types is generated: soil waste, from oil spilling onto soil during accidents; natural waste, from oil spillages sedimentation on the bottoms of water bodies; and tank waste, generated in oil storage tanks and sludge pits.

Remediation of technogenic landscapes is one of the urgent problems of modern times, especially with regard to oil production areas. The choice of the treatment methods for such territories is determined by the climate, the type, level and nature of contamination, the landscape peculiarities, and by the used technologies of oil processing and transportation.

Ecological remediation of the contaminated soil can be performed using two methods. The ex siti technology implies removing the contaminated layer by excavation and treatment of the contaminated soil. The in siti technology means the territory rehabilitation through the methods of phytoremediation. The technology of phytoremediation, that is using plants and microorganisms associated with them to remedy the contaminated objects, is the most preferential one [1-7]. This technology ensures the stability of the treatment process thanks to the high adaptive potential and mutualistic interactions between plants and microorganisms, does not consume much energy as it operates on solar power used in the process of photosynthesis, and therefore, it is a cost-effective and aesthetically attractive method.
of cleaning the contaminated objects. Phytoremediation does not require topsoil stripping, can be used for big areas, and facilitates the preservation and improvement of the environment as it is related to enrichment of soil and increasing of its fertility. The root system of plants contributes to the enhancing of gaseous interchange in the deep layers of soil and water, and to the development of oil-oxidizing microbiota in natural environment, which has been exposed to contamination by oil and which in normal conditions is characterized with low temperature, insufficient biogenic elements, lack of oxygen and excessive acidity.

Scientific publications and patents propose multiple variants of fulfilling the technology of phytoremediation, which suggest to plant oil-contaminated territories with vegetation with microbial communities in its rhizosphere characterized with high microbial content, and at the same time with high emulsifying properties, meanwhile the biomass of the underground part of the vegetation amounts to no less than 71.8 g/m² on a dry weight basis, or 143.6 g/m² of the fresh weigh of the biomass. To implement this method, the following plants are used: red clover, white clover, awnless brome, browntop, couch grass, meadow grass, cocksfoot, timothy grass, meadow fescue, and common yarrow [8].

For the phytoremediation of the oil-sludge-contaminated soil, the plants screening has been performed, as a result of which the most promising species have been selected: autumn rye (*Secale cereale* L.), domestic rye grass (*Lolium perenne* L.), alfalfa (*Medicago sativa* L.), and awnless brome (*Bromopsis inermis* Leys)[9]. During the testing of cultivated plants (wheat, rye, marigold, Saint-John's-wort, and basil) with the use of Bacispecin biological preparation, it has been revealed that these plants are poorly suited for northern territories. Due to the northern extreme climatic conditions (short growing season, low temperatures, and barren soil), the process of revegetation and soil reclamation is slow [9].

Japanese researchers performed a screening of 33 species of plants with regard to their capability to utilize oil products, and recommended to us gazania for phytoremediation [10], as this flowering plant is distinguished for its high content of oxidizing enzymes.

In Israel, scientists suggest using vetiver bunchgrass (*Vetiveria zizanioides* L.), a perennial herb of the family Poaceae, to treat oil-contaminated soil [11].

Scientists from South Sudan tested 12 species of local plants: *Sorghum arundinaceum* Desv., *Oryza longistaminata* A. Chev. & Roehrich, *Hyparrhenia rufa* Nees, *Abelmoschus ficulneus* L., *Gossypium barbadense* L., *Nicotiana tabacum* L., *Sorghum bicolor* L. Moench, *Eleusine coracana* Gaertn., *Capsicum frutescens* L., *Zea mays* L., *Tithonia diversifolia* Hemsl. and *Medicago sativa* L., and for the purposes of remediation they recommended *H. rufa*, *G. barbadense*, *O. longistaminata*, *T. diversifolia* and *S. arundinaceum* [12-17].

It has been proposed to dispose of the generated biomass by means of gasification; in particular, if we take the biomass remaining from poplar, used for soil phytoremediation, there is a worked-out technology of gasification in fluidized bed with production of synthetic gas. It has been proved that toxicants removed from soil do not contaminate the gas, and it can be used for energy generation purposes without any effects on the environment [18].

For phytomelioration, such crop as rhizome Poaceae grasses are used, which are the most promising species for phytomelioration of oil-contaminated soil, what can be explained by the intensive vegetative reproduction capability of these plants. Among such species is reed canary grass (*Phalaroides arundinacea* (L) Rausch), a perennial long-rooted grass of the family Poaceae. It can be found in pure and mixed coenoses in the Komi territory, in taiga zone and the southern border of tundra. *P. arundinacea* is a promising feed crop, especially for northern districts, as it is characterized with high crop yield, long life, and resistance to low temperatures, droughts, and diseases [19].

Lately, industrial hemp (*Cannabis sativa* L.) is being proposed to be used for phytoremediation. *Cannabis* (*Cannabis* L.), or hemp, probably originating from Asia, today is a totally domesticated species of plants being widely cultivated all around the world. In can also be found on other continents, in subtropical climates (or in case of its Finola subvariety, in moderate climates), but its presence there is a result of naturalizing (distribution in an alien environment) of plants introduced by
people (who usually escaped from local cultures) into a condition of secondary wild nature. This unique plant is distinguished for its high flexibility, fast growing and reproduction, and long root system with ample rhizosphere. Hemp was used after the catastrophe at the Chernobyl Nuclear Power Plant to remove radioactive substances. Today, cannabis is widely used for the contaminated soil treatment [20].

This paper studies the potential of the industrial hemp, being cultivated on the territory of Russia for food industry, to be used for phytoremediation for man-made oil production sites at the fields being developed by Irkutsk Oil Company.

2. Objects and methods of research

The object of research under this study is the soil from the territories of the Yaraktinsky oil and gas- condensate field. The sampling was performed in compliance with GOST 17.4.4.02-84. Samples were taken layer-by-layer, from the depth of 0-55 and 5-20 cm, using the X-shaped sampling method at the distance of 1, 5, 10, 15, 20 and 25 m off the drilling rig. The samples were tested in a certified laboratory for their concentrations of heavy metals and oil products, and for their physical-and-chemical and agrochemical properties, with the use of the well-known methods.

The properties of the samples of the technogenic soil taken at the Yaraktinsky field, as well as their concentrations of heavy metals are given in Table 1.

### Table 1. Physical-and-chemical and agrochemical properties, concentrations of heavy metals in the soil samples from the Yaraktinsky field.

| Indicator                  | Soil from the enterprise's territory at the distance of 1 m off the drilling rig | Soil from the enterprise's territory at the distance of 10 m off the drilling rig | Soil from the enterprise's territory at the distance of 25 m off the drilling rig |
|----------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| pH of aqueous suspension   | 2.8                                                                             | 3.7                                                                             | 4.6                                                                             |
| pH of salt suspension      | 2.9                                                                             | 3.9                                                                             | 4.5                                                                             |
| P2O5, mg/100 g             | not found                                                                       | not found                                                                       | 5.6                                                                             |
| NO3-, mg/100 g             | 0.7                                                                             | 1.1                                                                             | 1.9                                                                             |

Gross concentrations of metals and oil products

| Indicator | Soil from the enterprise's territory at the distance of 1 m off the drilling rig | Soil from the enterprise's territory at the distance of 10 m off the drilling rig | Soil from the enterprise's territory at the distance of 25 m off the drilling rig |
|-----------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Cu, mg/kg | 20.3                                                                             | 27.4                                                                            | 25.8                                                                            |
| Ni, mg/kg | 21.3                                                                             | 17.9                                                                            | 27.3                                                                            |
| Zn, mg/kg | 62.5                                                                             | 89.1                                                                            | 69.4                                                                            |
| Pb, mg/kg | 6.7                                                                              | 5.9                                                                             | 6.4                                                                             |
| Cd, mg/kg | 1.12                                                                             | 1.08                                                                            | 1.06                                                                            |
| As, mg/g  | 3.9                                                                              | 4.1                                                                             | 4.2                                                                             |
| Oil products, mg/g         | 14.3                                                                             | 21.5                                                                            | 10.9                                                                            |

Table 2 gives data on the general physical and hydrophysical properties of the soil samples.

### Table 2. General physical and hydrophysical properties of the soil.

| Sample                                           | Density, g/m³ | Particle density, g/m³ | Total porosity, % | Capillary moisture capacity, % |
|--------------------------------------------------|---------------|------------------------|-------------------|--------------------------------|
| Soil from the enterprise's territory at the distance of 1 m off the drilling rig | 1.25          | 2.09                   | 57.82              | 21.24                          |
| Soil from the enterprise's territory at the distance of 10 m off the drilling rig | 1.15          | 3.32                   | 67.359             | 27.43                          |
| Soil from the enterprise's territory at the distance of 25 m off the drilling rig | 1.26          | 2.68                   | 59.32              | 24.54                          |
The most severely contaminated samples from the distance of 10 m off the drilling were used. The soil samples were air-dried and sifted to remove litter, and next they were divided into 100 g portions per container for further experimenting. The soil from the field was combined with clean garden soil in various proportions, thoroughly mixed on a metal plate, and put back to the containers for studying. Polypropylene containers were perforated at the bottom to ensure drainage and aeration.

Then we took the seeds of hemp, which is sold at retail for the purposes of food industry. First, by the flotation method, we checked the viability of the seeds: we removed the seeds that floated up to the water surface, and considered those left on the bottom to be potentially viable. We planted ten hemp seeds in each container, and sprinkled them with deionized water at the intervals of two days till the completion of the experiment. The germinating ability of the hemp seeds in the soil samples under study was assessed in % as compared against the reference sample – clean non-contaminated garden soil. We repeated the experiments five times and processed the data statistics.

3. Results and discussion

Table 3 provides the data on the assessment of the germinating ability of the industrial hemp seeds in the soil under study.

| Soil under study                                      | Germinating ability, % |
|------------------------------------------------------|------------------------|
| Garden soil, (reference sample)                      | 100                    |
| Garden soil with mixed in 10% of the soil from the field | 71.5                  |
| Garden soil with mixed in 20% of the soil from the field | 65.2                  |
| Garden soil with mixed in 40% of the soil from the field | 51.2                  |
| Garden soil with mixed in 50% of the soil from the field | 42.1                  |
| Garden soil with mixed in 75% of the soil from the field | 29.3                  |
| 100% of the soil from the field without mixed in soil | 18.5                   |

The provided data show that the germinating ability of the seeds depends on the content of the contaminated soil. The lowest germinating ability is registered for the soil without the mixed in clean garden soil. This can be most likely explained by the fact that oil products hinder the growth and development of plants. The oil products that penetrate through the seed coat kill the seed germ. They can slow down the metabolic processes and hinder the processes of the water and mineral intake from the substrate. It has been found that the concentration of oil products in the soil after 2 weeks of seed sprouting decreases by the average of 40-45%.

4. Conclusion

In conclusion, it is worth noting that as a result of our research we have managed to ultimately prove that the seeds of industrial hemp can sprout in the contaminated soil of the Yaraktinsky field, and the plants can perform the phytoremediation function. Mixing in of a humus-based garden soil improves the germinating ability and the phytoremediation potential of industrial hemp in severely contaminated territories of production fields being developed in the northern districts of the Irkutsk Region. At present the Ecological Remediation Technology undergoes the on-site testing.

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**Acknowledgments**
The work was supported by Act 211 Government of the Russian Federation, contract No 02.A03.21.0011.