Assortment of herbaceous plants for remediation of soils contaminated with oil products and heavy metals

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Abstract. Biological remediation is the final stage of soil remediation. It is carried out to reduce and prevent the effects of technological disturbances. Plants can uptake and transform heavy metals, inorganic anions, oil products and pesticides. Recommendations were based on the practice experience and scientific researches. The quantitative chemical analysis of the soil pollutants demonstrated the presence of cations of heavy metals and oil products, and a rather high content of chlorides and sulfates was also detected. Such soils should be considered as saline. Therefore, plants for remediation should: a) correspond to the natural and climatic zone; b) show resistance to pollutants; c) plants must be salt tolerant. The composition consists of the following herbs. Medicago x varia Martyn is promising for areas with extreme environmental conditions. Agropyron tenerum Vasey is a good plant for phytoremediation of oil-sludge-contaminated soil. Festuca pratensis is well in universal, road, construction, sports lawns, and for special purposed lawns. Dactylis glomerata decreases gaseous mercury emission to the atmosphere and mercury mobility in soils. Phleum pratense have high phytostabilization potential in polluted soils and adaptation to soil pollution by this metals. That mixture is resistant for contaminated soils.

1. Introduction

Soil resistance to anthropogenic pollution is known to be in dependence on its physicochemical and agrobiological properties [1]. Biological remediation is the final stage of soil remediation. It is carried out to reduce and prevent the effects of technological disturbances. The biological stage includes a complex of agrotechnical and phytomeliorative measures. They are aimed at improving the agrophysical, agrochemical, biochemical and other properties of the soil to restore natural soil fertility.

Phytoremediation is a relatively new and actual method of purification of waste and natural waters and soils as well as decontamination of air pollutants [2]. It is use of green plants to absorb or decontaminate organic or inorganic toxicants in the environment [3, 4]. It is a promising technology for the revegetation of polluted territories. Researches [5-9] are devote to the quantitative characteristics of uptake of heavy metals, sulphates, nitrates, and low-molecular substances by plants from industrial and residential wastewater and model solutions. Plants can uptake and transform heavy metals, inorganic anions, oil products and pesticides.

Soils contaminated with organic substances are an important issue. In some areas, these are the main causes of pollution, or the second after contamination from waste disposal [10]. Bioremediation
technologies have been developed in the last decades and are increasingly used to mitigate environmental accidents and systematic contaminations. There are bioremediation technologies for different types of contaminated matrices, bioremediation agents and contaminants. The technologies for water (53%), soils (36%), and sludges (11%) are growing yearly at nearly constant rates. The bioremediation agents are predominantly bacteria (57%), enzymes (19%), fungi (13%), algae (6%), plants (4%) and protozoa. The major contaminants are oils (38%), followed by metals (21%), organic waste (21%), polymers (10%), food (5%), cellulose (5%) and biodiesel. The soils bioremediation technology of oil is centred on bacteria usage (about two thirds of the articles and patents), being fungi a technology with critical mass and high growth potential. A recent trend in oil bioremediation of soils is the combination of bioremediation agents (fungi and bacteria) in the same process, thus making the process more robust to environment changes [11].

Environmental contamination due to heavy metals is of serious ecotoxicological concern worldwide because of their increasing use at industries. Due to non-biodegradable and persistent nature, heavy metals cause serious soil/water pollution and severe health hazards in living beings upon exposure. Heavy metals can be genotoxic, carcinogenic, mutagenic, and teratogenic in nature even at low concentration. They may also act as endocrine disruptors and induce developmental as well as neurological disorders, and thus, their removal from our natural environment is crucial for the rehabilitation of contaminated sites. To cope with heavy metal pollution, phytoremediation has emerged as a low-cost and eco-sustainable solution to conventional physicochemical clean up methods that require high capital investment and labour alters soil properties and disturb soil microflora. Phytoremediation is a green technology wherein plants and associated microbes are used to remediate heavy metal-contaminated sites to safeguard the environment and protect public health. Phytoremediation is a sustainable remediation technology for the management of metal-contaminated sites [11].

2. Materials and methods
Recommendations were based on the practice experience and scientific researches. The range of perennial herbs was selected on the basis of analysis of recommendations [12], as well as taking into account the resistance of plants to oil products, heavy metals, and salinization of the soil. Sources in which there were descriptions of plant species were analysed.

3. Results and discussion
To accelerate the processes of sludge formation, to restore and form a root-inhabited layer and its enrichment with organic substances, it is advisable to sow grass mixtures from several types of herbs, including cereals and legumes. The herbal mixture is created by combining species of various life forms. Preference is given to species that mimic the combination of plants in natural communities. The selection of herbs provides good sodding of the territory of the landfill, frost and drought resistance, durability and rapid regrowth after mowing.

The problem of the protection of the environment and the preservation of biological diversity touched significantly to anthropogenically transformed landscapes which were subjected to increasing technogenic and recreational impact. Gardening of urbanized areas by creating a system of protective plantings of different types and categories becomes particularly important in solving the problem [13].

The range of perennial grasses, proposed in [12], includes the following types of herbaceous plants:

- Dactylis glomerata
- Trifolium pratense
- Poa pratensis
- Poa trivialis
- Festuca rubra
- Agrostis alba
- Agropyron tenerum Vasey.
Phleum pratense

This list should be optimized due to the fact that the quantitative chemical analysis of the soil pollutants demonstrated the presence of cations of heavy metals and oil products, and a rather high content of chlorides and sulfates was also detected. Such soils should be considered as saline. Therefore, plants for remediation should: a) correspond to the natural and climatic zone; b) show resistance to pollutants; c) plants must be salt tolerant.

Trifolium pratense has low salt resistance [14]. Poa pratensis and Poa trivialis are tolerant to flooding with melt water, but they are negative to excess of acidity and salinity. Agrostis alba is not resistant to salinization [15]. Agropyron tenerum Vasey refers to highly salt-resistant grass [14]. The most salt-tolerant crops are Agropyron sp., Agrostis sp. and Sorghum sudanense [16]. Phleum pratense and Bromus inermis have less salt tolerance than Agrostis sp. [17] The absence of oppression of plants growing in heavily polluted areas is associated with a number of adaptive reactions. It indicates the possibility of using of Elytrigia repens, Phleum pratense and Dactylis glomerata for phytostabilization of soils contaminated with heavy metals in the Northern zone of Russia [18].

The following composition of the herb mixture is proposed:

- Medicago x varia Martyn 20%
- Agropyron tenerum Vasey. 20%
- Festuca pratensis 20%
- Dactylis glomerata 20%
- Phleum pratense L. 20%

That composition of the herb mixture will exist for a long time.

Medicago x varia Martyn is a perennial plant. Height is 70-120 cm. Stems are glabrous or slightly pubescent, branching, leafy. Leaflets are elongate-elliptic or ovate-rounded, glabrous or slightly pubescent, stipules wedge-shaped, pointed. Inflorescence is cylindrical capitulate rather loose brush, its length is 3-5 cm. Flowers are variegated; the colour is from light blue to dark purple and dirty yellow. Beans are large, spiral, kidney-shaped; the colour is light yellow, olive or dark brown. The plant grows quickly in spring and after mowing. The species is characterized by high ecological plasticity. Medicago x varia Martyn is more resistant than Medicago sativa, so it is more promising for areas with extreme environmental conditions. The plant is used for tilling meadows and pastures, as well as slope lands, which are destructed by water and wind erosion. Medicago x varia Martyn is characterized by high winter- and drought resistance, undemanding to soil; it is resistant to major diseases and pests. It is responsive to irrigation and soil fertility. The plant is long-lived, in the cultural herbage it can be preserved for more than 10 years. It significantly improves the structure and fertility of the soil. It is a valuable precursor to many crops. The sowing rate is 10...14 kg / ha [19].

Agropyron tenerum is a perennial grass with a loose bushing. It differs from Agropyron repens because it has not rhizomes. The height of plant is 50 - 100 cm. The plant is most widespread in the forest-steppe and steppe zones (except dry steppes), as well as in the Far East, Western and Eastern Siberia. It has well developed fibrous root system, which penetrates to a depth of more than 1 m. The bush is quite dense, with numerous stems. The stem is erect and thin. The leaves are narrow light or dark green, as they grow become stiff. The inflorescence is a loose spike 10-12 cm long. Spikelets are 2-3-flowered and appressed to the stem. Grains have oblong-linear shape; the weight of 1000 grains is 2.8-3.0 g. This culture is undemanding to soils, it can grow on any soils except damp and boggy. Black earth (chernozem) and gray forest soils are the best soils for it. It is frost resistant, but it is damaged by a glass of ice. The plant tolerates soil salinization well. It does not withstand prolonged flooding, but it responds positively to watering. It is used for hay and grazing. In the year of sowing the yield is low. The maximum yield is in the second or third year, in the fourth year it falls sharply. It is used in field crop rotations as an additional crop. The norm of sowing of seeds in pure form is 17...20 kg/ha, in grass mixtures is 13-15 kg. It is a good plant for phytoremediation of oil-sludge-contaminated soil [20].
Festuca pratensis is a perennial grass. It has a strong fibrous root system, sometimes it forms short creeping rhizomes. The roots penetrate to a depth of more than 2 m, so the plant is more resistant to drought. The main part of the roots is located in the arable horizon. The stem is rounded, smooth, erect, reaching a height of 120-170 cm. Shortened, vegetative, well-leaved shoots dominate. The leaves are linear, flat, with a shiny underside. The base of the leaf blade passes into the ears covering the stem. The leaves at the base are located in the basal rosette; the leafiness of the stems is only 29%. The inflorescence is a panicle. Inflorescence is compressed before flowering and after it and it is spreading during flowering. Seeds are enclosed in a floral film of greyish colour. The weight of 1000 seeds is 1.2...2.4 g. Seeds of Festuca pratensis retain germination for 5 years under favourable conditions. It is one of the best plants for pasture or hay mixtures. It has high feed value; feed advantages are above Phleum pretense. It is resistant to grazing and haying. Festuca pratensis is undemanding plant. It is characterized by high winter-, frost- and drought resistance as well as waterlogging. It can grow on slightly acidic soils (pH 5-6); it withstands salinization better than Phleum pratense (0.6-0.8% of salts from the dry mass of the soil). Festuca pratensis is well in universal, road, construction, sports lawns, and for lawns with which the slopes and shores are tinned. The seeding rate is 8...15 kg / ha [21].

Dactylis glomerata is a perennial grass up to 150 cm or more in height, with short underground shoots or without them. The root system is powerful; it penetrates into the soil to a depth of more than 1 m. The leaves are linear; often they are flat or folded along, sharpened at the edges, and thinly pointed. Inflorescence is compressed laterally panicle with crowded spikelets. The spikelets consist of 3-6 flowers. The grain is oblong and elongated. The colour of grain is greyish-yellow. The species is undemanding to soil conditions, resistant to drought and salinization. It grows in meadows, forest glades, roadsides. It is used as a valuable forage plant. Use of this species is known to strengthen soils disturbed due to anthropogenic impact. Seeding rate in pure form is 16...20 kg / ha. Cultivation of Dactylis glomerata decreases gaseous mercury emission to the atmosphere and mercury mobility in soils [22].

Phleum pratense L. is a perennial loose-leaf riding grass with a swollen base of stem and short creeping rhizomes. The root system is spongy; it penetrates shallow into the soil. Stems up to 120 cm tall, they are straight or bent in the lower internodes. The leaves are rough, green or grey-green. Leaf blades are wide, pointed at the ends. The inflorescence is a dense spike-like panicle with cylindrical shape. Spikelets with one flower, they are strongly flattened from the sides. The grain is small, ovoid or elliptical, membranous. Plants of this species have increased winter hardiness. They grow well on all soil types regardless of acidity; however they are not resistant to prolonged drought and high temperatures. Phleum pratense L. grows in meadows, forest glades, roads, fields in almost all climatic zones. The plant is widely used as a forage crop, as well as to protect soils from erosion. It is a valuable cereal component in mixtures with legumes. Seeding rate in pure form-8-10 kg / ha. Phleum pratense have high phytostabilization potential in copper polluted soils and adaptation to soil pollution by this trace metal [23].

In the first year of the biological stage, soil preparation is carried out. It includes cultivator treatment, introduction of the main fertilizer with subsequent harrowing and pre-sowing rolling. All technological techniques for soil treatment can be carried out in the spring. The early spring sowing period is recommended. The way of sowing of the grass mixture is separate-ordinary method. Measures for the care of crops are aimed at the early formation and sustainable existence of grass stands. These measures include fertilizing with mineral fertilizers, sawing of herbs in bare areas and watering on drying soils.

**4. Conclusion**

It can be concluded basing on the analysis of properties of different grass that a selected assortment of herbs will allow to get stable herbage in unfavourable environment conditions. It is recommended to choose species resistant to major pollutants. The composition consists of the following herbs: Medicago x varia Martyn, Agropyron tenerum Vasey., Festuca pratensis, Dactylis glomerata, and Phleum pratense L.. That mixture is resistant for soils contaminated with cations of heavy metals and oil products with high content of chlorides and sulfates.
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