

METHODS OF *IN SITU* REMEDIATION WITH THE USE OF NATURAL PROPERTIES OF ROCKS AND LIVING ORGANISMS

Summary

The aim of the work was to improve the effectiveness of selected methods of *in situ* remediation of soils, to varying degrees polluted with petroleum substances and heavy metals, by using the natural properties of rocks and living organisms, mainly plants.

Studies were carried out to select the best natural materials used in the phytostabilization process to prepare contaminated soil before the introduction of appropriate plant species. On the basis of research, combining field and laboratory research, it was determined which species of plants, especially those native to the flora of Poland, have the best remediation properties, and using the natural properties of rocks, it was determined which of them significantly affect the elimination or immobilization of pollutants.

A commercially available enzymatic microbiological preparation from Cleanbacter Instytut Technologii Mikrobiologicznych Sp. z o. o. was used for the process of bioremediation of contaminated soil. In the bioremediation process, aerobic bacteria were used, e.g. from the genus *Bacillus Sp.*, *Pseudomonas fluorescens* as well as enzymes and biosurfactants.

In the process of phytoremediation, various plant species were tested: a mixture of flowers and grasses forming the so-called "flower meadows", *Morus alba* white mulberry, *Salix viminalis* willow, *Hippophae rhamnoides* sea buckthorn and *Symphoricarpos albus*, which were selected for the mechanisms of plant response to particular pollutants.

The research focused on the increased effectiveness of the plant's purifying action, also by changing the soil properties, positively influencing the course of the purification process by using stabilizing additives in the form of lime, mineral sorbent with montmorillonite, fine-grained lignite fraction and basalt flour used in the pot experiment of phytoremediation assisted with using sea buckthorn *Hippophae rhamnoides* seedlings as a remedial agent.

Research works on improving the methods of supporting soil self-cleaning were carried out both in laboratory conditions, using experimental plots prepared for this purpose, and in "training ground" conditions, on the example of actual areas contaminated with various substances.

As research has shown, phytoremediation is a relatively long-term, but effective method in soil purification. Both the process of phytoremediation and soil bioremediation contributed to the reduction of pollution and to obtaining the concentration of pollutants within the limit values specified in the Regulation of the Minister of the Environment of September 1, 2016 *on the method of assessing land surface pollution* (Journal of Laws of 2016, item 1935).

In the process of phytoremediation of soils contaminated with oil derivatives, the effective, most economical, but long-term solution turned out to be the use of a mixture of flowers and grasses

forming "flower meadows". In polluted areas with small areas or with spot pollution, phytoremediation with the use of *Morus alba* white mulberry seedlings turned out to be an equally effective method of remediation of soils contaminated with oil derivatives. In turn, the fastest and effective method of *in situ* remediation of soils contaminated with petroleum hydrocarbons is bioremediation. In the case of phytoremediation of soils contaminated with heavy metals, the fastest method of remediation turned out to be the use of sea buckthorn *Hippophae rhamnoides* and *Salix viminalis* willow seedlings.

Based on the pot experiment of introducing soil additives and the obtained test results, it was found that the soil additive in the form of bentonite with montmorillonite (at a dose of 5%) can be considered as the substance that most effectively optimized the process of phytoremediation of soil contaminated with heavy metals using *Hippophae rhamnoides* sea buckthorn seedlings.