Oil Polluted Soils Phytoremediation by Grazing Culture

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Abstract

Total petroleum hydrocarbon (TPH) polluted soils cannot be used for agricultural, industrial or recreational activities. They are potential sources of contamination of soil, surface water and groundwater. They also directly and indirectly alter the landscape. Phytoremediation of soils polluted with total petroleum hydrocarbon with suitable plants is a technology that requires low cost and traditional plant cultivation strategies. In this study are presented models of phytoremediation of polluted soils with 79.42 ± 3.9 $g \cdot kg^{-1}$ DM. For successful phytoremediation process the TPH polluted soil was fertilized with sewage sludge mixed with varying amounts of fly ash. From the analytical study of the experimental data we could develop the model of phytoremediation by bird's foot trefoil culture (*Lotus corniculatus*). The model applies in the case of oil polluted soil fertilized with a fertilizing agent, *i.e.* sewage sludge, in an amount of 250 g per pot mixed with fly ash in a ratio of 1: 1─5:1 weight parts. The TPH amount lost from polluted soil on a 12-month period was up 88%.

Introduction

Plants can decrease total petroleum hydrocarbon (TPH) content of polluted soil by absorbing pollutants and translocations them in the plant. In plant tissue pollutants can be seized, metabolized or eliminated through transpiration, etc. The plant development in TPH polluted soil to be promoted by micro- and macro- nutrients added. The necessary nutrients need for plants growth was done by sewage sludge fertilizer. Furthermore sewage sludge in soil inserted microbial dowry [1, 2]. This stimulates biodegradation of carbon products by specific metabolism of rhizosphere area. Roots are the immediately active plant's parts to access soil different compounds that can also be petroleum hydrocarbons. The roots of the plant act directly on the soil. They break soil aggregates coated with petroleum products and increase soil aeration capacity. The roots of the plant help to increase the bacterial activity in the regions surrounding the root. Plant roots directly contribute to limiting the movement of pollutants, in soils in that they remove water and thus reduce the movement of water with impurities through channels formed among soil aggregates. On the other hand high toxicity of TPH was attenuated by fly ash as temporary adsorbent with high porosity [3.4]. Fly ash is used as fertilizer or amendment to enhance the physic-chemical properties of soil [5.6]. The presence of large amounts of TPH in soil requires the management of these lands. Is welcome selection of plant species for phytoremediation [7]. The strategy for the decontamination of polluted soils with high amounts of TPH in this study comprises the steps of: 1. soil characterization, 2. identifying agricultural works that can be applied in polluted area, in particular soil fertilization, 3. selecting crops tolerant of polluted soil toxicity, *i.e.* grasses, legume, etc.. This study presents the results on phytoremediation of soils polluted with 79.42 ± 3.9 $gTPH \cdot kg^{-1}$ D.M. fertilized with sewage sludge mixed with varying amounts of fly ash. From the comparative study of the experimental data we could elaborate the phytoremediation model by culturing bird's foot trefoil (*Lotus corniculatus*).

Experimental

TPH polluted soil was taken from the surroundings of an oil field in operation. The soil was cleaned, dried and ground. Petroleum products cause strong adhesion between soil particles forming larger aggregate. After breaking into smaller units of the large aggregate of soil, resulted soil aggregates with sizes between 1-3 cm. Soil contaminated with TPH load of 20% was mixed with unpolluted agricultural soil. Unpolluted agricultural soil was dried, cleaned of various plant residues, pebbles, etc., crushed and homogenized. Agricultural soil screening was performed by sieve with a mesh size of 1 mm. The TPH polluted soil with a large amount of 20% was mixed with unpolluted agricultural soil. Mixing was performed in proportion of polluted soil: unpolluted soil of 1:2 wt.: wt. The amount of TPH in the soil mixture resulting from mixing the polluted soil with unpolluted soil was 79.42 ± 3.9 $gTPH \cdot kg^{-1}$ D.M. The experimental study included experimental variants of soil contaminated with an amount of 79.42 ± 3.9 g $gTPH \cdot kg^{-1}$ D.M. untreated / treated by fertilizing with sewage sludge in amount of 250g per vegetation pot. As a temporary agent of adsorption of TPH from the soil were used different amounts of fly ash 50, 25, and 500 g fly ash per pot, respectively. The experimental study variants were: **P** - uncultivated polluted soil; **PB** - cultivated polluted soil fertilized with sewage sludge; **PB 1** - polluted soil fertilized with sewage sludge mixed with fly ash 50g per pot and cultivated with plant; **BC** - polluted soil fertilized with sewage sludge mixed with fly ash 250 g per pot and cultivated with plant and **PB 3** - polluted soil fertilized with sewage sludge mixed with 500 g fly ash per pot and cultivated with plant. The plant species used in phytoremediation process was the bird's foot trefoil (*Lotus corniculatus*). Characteristics fertilizer sewage sludge used were: moisture 88.6%, organic matter content of 33.4%, 0.55% total nitrogen, phosphorus 0.37% and pH = 6.5. The experiment was carried out in pots with 6.5 kg of untreated/treated polluted soil. Cultures were performed in triplicates each, a total of 15 pots. The experimental unit was placed during the study outdoors. In the cold winter pots were covered with straw. The method of TPH content of polluted soil analysis was presented by Masu et al. [8].

Results and discussion

Table 1 describes the evolution of the crop monitored for 12 months. The initial concentration of TPH in soil was 79.42 ± 3.9 $gTPH \cdot kg^{-1}$ D.M. It is noted from Table 1 that the bird's foot trefoil plants sprout late on the experimental variant treated with sewage sludge in fly ash absence. There is a two weeks delay compared to the other plants in the experimental variants. Plants develop with difficulty. They form a small number of offshoots. Plants suffer during growth showing such as yellowing and drying of leaves gradually.

Table 1 Vegetation cover degree of the experimental variants seeded with bird's foot trefoil during the monitored period of 12 months. (3 replicates for each experimental variant, total of 15 variants)

Experimental variants	P*	PB	PC3	BC	PB1
Plant sprouting		3-4 week	2 week	2 week	2 week
Plant cover degree during the first year [%]		5-10	15-18	25-35	25-35
Number of offshoots		1-2	1-3	2-3	2-3
Plant cover degree during the second year [%]		**	80-85	85-95	80-90
Number of offshoots			3-4	5-6	5-6

* P uncultivated polluted soil; ** PB polluted soil fertilized with sewage sludge. The plants dried in winter.

During the cold winter plants on this experimental variant dried**.** In comparison, the plants on the variants fertilized with sewage sludge mixed with fly ash sprouted in larger numbers. Plants gradually occupied up to 35% of the sown surface in the first year. The plants were more vigorous. They showed a greater number of offshoots than the ones grown in the absence of fly ash fertilized variant. The plants endure during winter. In the second year of culture, plants grown on variants fertilized with sewage sludge mixed with fly ash will continue to develop. They will form a double number of offshoots compared to the first year. Moreover, they will cover up to 80- 95% of the sown area. Table 2 shows the variations in the content of petroleum products after 2, 4, 9 and 12 months of vegetation respectively in all the studied soil experimental variants: cultivated and uncultivated plants. From Table 2 it is observed that in the monitored period of 12 months from the polluted soil TPH content decreases by 23.0 ± 2.8 $gTPH\cdot kg^{-1}$ D.M. The decrease is due to volatilization phenomena of some oil components. From the polluted soil fertilized with sewage sludge in the absence of fly ash, TPH content decreases by 37.5 ± 2.0 $gTPH\cdot kg^{-1}$ D.M. The decrease is due to volatilization phenomena of TPH and metabolic phenomena performed by the biological heritage of the sewage sludge. The polluted soil fertilized with sewage sludge and fly ash, cultivated with bird's foot trefoil, the content of TPH decreased by 68.5-70.0 $gTPH\cdot kg^{-1}$ D.M. The addition of sewage sludge mixture and fly ash in a ratio with 1:1─5:1 weight parts decreased the most the TPH content. The efficiency of TPH reduction in soil during the period of 12 months was up 88%. The addition of fly ash in larger quantities did not determine the expected plant growth efficiencies on the variants and the advanced reduction of TPH content.

Table 2 Variation of TPH content from the experimental variants of soil studied and cultivated with bird's foot trefoil on the monitored period (initial concentration 79.42 ± 3.9 gTPH·kg^{-1} D.M.). 3 replicates for each experimental variant, total of 15 variants)

No	Vegetation period	Experimental variants/ TPH content in soils g·kg^{-1} D.M.				
		P*	PB**	PC3	BC	PB1
1	2 months of vegetation	68.8±5.8	64.8±5.2	74.±6.8	55.3±5.0	64.6±5.2
2	4 months of vegetation	59.5±5.4	52.0±4.8	58.4±5.7	29.5±3.8	47.3±4.8.
3	9 months of vegetation	55.5±5.5	46.0±4.7	47.2±4.8	14.4±2.6	28.5±3.3
4	12 months of vegetation	55.5±5.	42.0±4.3	11.6±1.8	9.44±1.5	9.97±1.0

* P uncultivated polluted soil; ** PB polluted soil fertilized with sludge. The plants dried in winter.

It can be seen a reduced decrease of TPH in soil in winter when the plant metabolism and that of soil biocenosis was slower. The analysis of the experimental data presented in Table 1 and 2 is seen that in the variants fertilized with sewage sludge mixed with fly ash bird's foot trefoil crops gradually develop occupying the sown areas. They develop normally under the conditions specific to the climate in the west part of the country. In conclusion it was possible to develop a model of phytoremediation of the polluted soils with 79.42 ± 3.9 gTPH·kg^{-1} D.M. by bird's foot trefoil (*Lotus corniculatus*) culture. To form and maintain a layer of plants is needed a treatment of the TPH polluted soil with fertilizer agent, *i.e.* sewage sludge in an amount of 250g per pot mixed with fly ash in a ratio of 1:1─5:1 wt. :wt. parts. In Figure 1 are shown the bird's foot trefoil cultures formed on the experimental variants in pots after 12 month of vegetation.

Figure 1. In pots experimental variants from *Lotus corniculatus* after 12 months

Conclusions

Bird's foot trefoil cultures have developed on soils contaminated with 79.42 ± 3.9 gTPH·kg^{-1} D.M. gradually occupying the sown areas. In the 12 months of monitoring the crop the areas occupied reached 80-95%. For the application of the phytoremediation process with bird's foot trefoil plants of soil contaminated with TPH was necessary fertilization with a fertilizer agent *i.e.* sewage sludge. For culture maintain was necessary sewage sludge mixing fly ash in

1:1─5:1 wt.: wt. The process of phytoremediation for soils contaminated with 79.42 ± 3.9 $gTPH \cdot kg^{-1}$ D.M. by bird's foot trefoil (*Lotus corniculatus*) culture for an appropriate treatment of soil can render these soils back to the agricultural circuit. Soil TPH loss was up to 70 $gTPH \cdot kg^{-1}$ D.M. for 12 monitored months. Furthermore efficiencies reduction of soil TPH planted with bird's foot trefoil were up 88%.

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