Lotus corniculatus Crop Growth in Crude Oil Polluted Soil. Part1 Total Petroleum Hydrocarbons Reduction of Polluted and Cultivated Soil

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Abstract
The use of power plant fly ash, by its physical-chemical properties, can significantly change the characteristics of soils polluted with oil (Total Petroleum Hydrocarbons, TPH), in their rehabilitation process, if combined with biodegradable organic materials, wastes such as sewage sludge from municipal wastewater treatment plant. Maintaining vegetation on soils polluted with 80.5±3.9 $g\cdot kg^{-1}$ D.M. of TPH under perennial regime specific to bird's foot trefoil (*Lotus corniculatus),* demonstrates the tolerance of the plant to the created conditions by the treatment of polluted soil with adequate amounts of fertilizer and fly ash from burning coal in power stations. The addition of 50-500 g fly ash per vegetation pot equipped with crude oil polluted soil mixed with 250 g sewage sludge per pot has reduced the oil content in the soil, in two ways: on the one hand influenced by the state of development of plants and on the other hand by weather conditions (alternation of seasons). The amount of TPH lost during the 16 months of vegetation in soils polluted with 80.5±3.9 $g\cdot kg^{-1}$ D.M. was 73.3-77.5 $g\cdot kg^{-1}$ D.M.

Keywords: fly ash, *Lotus corniculatus,* phytoremediation, polluted soil, sewage sludge, Total Petroleum Hydrocarbons.

1. Introduction

The causes of oil pollution in our country are different, from region to region, depending on the technological process stages: extraction, collection, refining, transport, tapping etc. In general, pollution occurs due to obsolescence or physical damage to installations, incidental or caused losses. In Timis County, according to a study of county government, there are large areas that, in one form or another, have been contaminated with toxic chemicals, solvents and petroleum products. Areas of extraction, shipment and processing of petroleum products show old or recent massive pollution. According to the monitoring of these locations, there are reported over 10 important sites with high pollution in the county. The characteristics of soils affected by the presence of oil pollutants with hydrophobic character, are: moisture, soil texture, different distribution of pollutants in soil pores between aggregates of soil, properties of expansion or constriction of the soil pores (especially in clay soil), water holding capacity etc. The hydrophobicity and toxicity of pollutants have caused a high potential for modification of chemical and physical properties of soils and ultimately, the changing of soil biological activity [1].

The improvement of the agricultural characteristics of soils polluted with oil products can be achieved using fertilizers that add the necessary nutrients for plant growth [2]. Furthermore, the additions of amendments are

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needed, that besides the micronutrients introduced, present the capacity to diminish the stress due to pollution. On the other, with each passing year, the global production of sewage sludge is increasingly growing, whereby the evaluation of its applicability in land restoration is essential. The results of studies suggest that composted sewage sludge determined the improvement of the agricultural land characteristics of soils destroyed by human activities [3-5]. Also, sewage sludge presence reduces the bioavailability of metals, such as: Cd, Cu, Pb and Zn and stimulates seed germination if associated with a fly ash amount of 10% weight vs. the weight of the oil polluted soil [6-9]. The fly ash can have different effects on plants depending on the polluted soil on which it is applied. It can increase significantly the crop, but it can also be a source of heavy metals, which lead to an increase bioaccumulation in plant tissues. Based on the physical-chemical parameters of the fly ash and sewage sludge mixture, soil treatment with this mixture is a particularly convenient alternative for destroyed soils by human activities [10-11]. In the present study, bird's foot trefoil, (*Lotus corniculatus)*, phytoremediation processes are monitored for soils polluted with 80.5±3.9 $g\cdot kg^{-1}$ D.M. through: 1. variation of TPH content in polluted soils untreated/treated with fertilizer-sewage sludge mixed with fly ash; 2. the reduction efficiency of TPH in soils treated/untreated and cultivated with bird's foot trefoil, (*Lotus corniculatus)*, 3. the influence of the amount of fly ash on the process of phytoremediation with bird's foot trefoil crop.

2. Materials and methods

Polluted soil was taken from the surroundings of oil wells in operation. The soil was cleared of stones and other impurities cleaned and was dried and ground. Oil products cause strong adhesion between soil particles forming large aggregates. After breaking into pieces of the large soil units, resulted soil aggregates with sizes from 1 to 3cm. Polluted soil, with an initial loading of 20% TPH, was mixed with non-polluted agricultural soil. The non-polluted agricultural soil has been dried, cleaned of various plant residues, pebbles etc., crushed and homogenized. The non-polluted agricultural soil has been sieved with sieves of mesh size of 1 mm. The soil polluted with 20% of TPH was mixed with non-polluted agricultural soil, in a ratio of 1:2, weight: weight. The amount of oil in the soil mixture was 80.5±3.9 $g\cdot kg^{-1}$ D.M. The experimental study block included experimental variants of soil contaminated with an amount of 80.5±3.9 $g\cdot kg^{-1}$ D.M. untreated/treated with sewage sludge in the amount of 250 g per vegetation pot and different amounts of fly ash. The experimental variants were: P- non-cultivated polluted soil; P0-cultivated polluted soil fertilized with sewage sludge; P1 cultivated polluted soil, fertilized with sewage sludge in mixture with 500 g fly ash per vegetation pot; P2–cultivated polluted soil, fertilized with sewage sludge in mixture with 250 g fly ash per vegetation pot; and P3-cultivated polluted soil, fertilized with sewage sludge in mixture with 50 g fly ash/vegetation pot. The plants used on the experimental variants belonged to the bird's foot trefoil species (*Lotus corniculatus*). Sewage sludge characteristics were: 88.6% moisture, 43.4% organic matter content, 0.55% total nitrogen, 0.37% phosphorus, pH=6.5. The experiment has been carried out in vegetation pots with 6.5 kg of soil. Plants were cultivated in pots, in triplicates, with a total of 15 vegetation pots. The experimental block was placed outdoors during the study. In the cold period of winter pots were covered with straw. TPH analysis method of oil polluted soil was presented by Mâșu et al. [12].

3. Results and discussion

The bird's foot trefoil (*Lotus corniculatus*) crop studied developed on the experimental variants performed in vegetation pots equipped with soils polluted and fertilized in the absence/presence of fly ash from power plants. Bird's foot trefoil crops have developed on the variants of fertilized soil and have reached maturity. The plants were harvested in the 12^{th} and 13^{th} months from seeding (first harvest and the second harvest). Figure 1 shows average value of TPH quantities of polluted soils untreated/treated, cultivated/non-cultivated with bird's foot trefoil, (*Lotus corniculatus*) during the period of 16 months of monitoring.

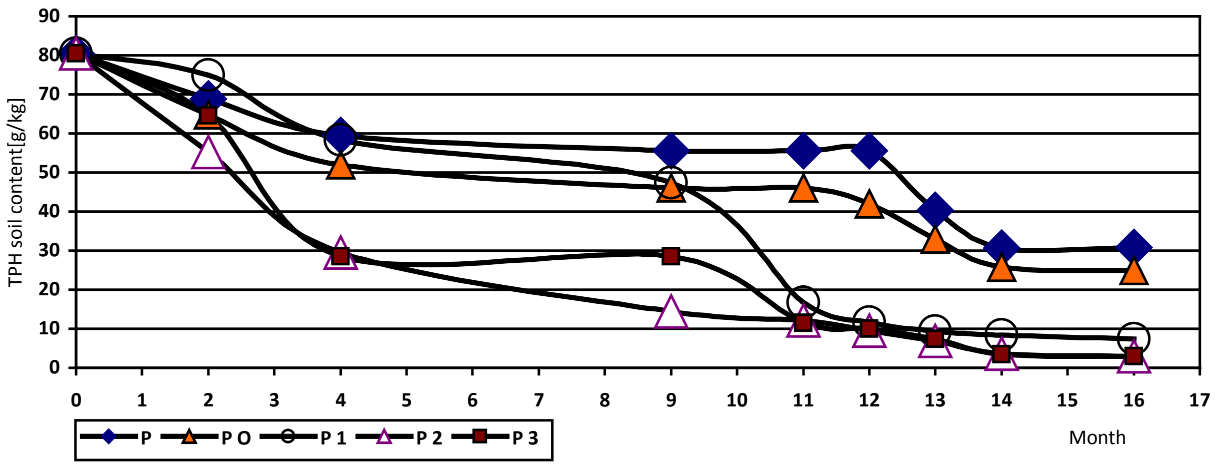

Figure 1. TPH variations of polluted soils untreated/treated, cultivated / non-cultivated with bird's foot trefoil (*Lotus corniculatus*), during the period of 16 months of monitoring
P- non-cultivated polluted soil; P0 – cultivated polluted soil fertilized with 250 g sewage sludge per vegetation pot; P1 cultivated polluted soil, fertilized with sewage sludge in mixture with 500 g fly ash per vegetation pot; P2 – cultivated polluted soil, fertilized with sewage sludge in mixture with 250 g fly ash per vegetation pot; P3 - cultivated polluted soil, fertilized with sewage sludge in mixture with 50 g fly ash per vegetation pot

From Figure 1 curves can be noticed that:

1. In the polluted, untreated, and uncultivated soil, in the first months of vegetation (months 1-4), there has been a reduction average value in TPH content of 5.0 g·kg^{-1} D.M., monthly. Between months 4-12, there is a plateau showing small variations in TPH. In this period, of the polluted soil, there has been lost a total of TPH up to 5.0 g·kg^{-1} D.M. (up to maximum 0.5 g·kg^{-1} D.M. per month). In the next period (months 12-14), the rate of disappearance of TPH in the soil was of 7.5 g·kg^{-1} D.M., monthly (average value). During autumn, the rate of loss of TPH in soil was reduced to<1 g·kg^{-1} D.M. The average loss of TPH in soil polluted, untreated and uncultivated during the 16 months period was on the average of 49.7 g·kg^{-1} D.M.
2. The addition of fertilizer and forming of a small crop of bird's foot trefoil on the variant P 0 caused a slight increase in TPH mean loss during the 16 months, of 55.5 g·kg^{-1} D.M. Plants culture dried after 3 months.
3. In the cultivated polluted soil fertilized with 250 g of sewage sludge/pot and the addition of 500 g ash/pot (variant P1), in the first months of vegetation there has been a average reduction in TPH content of 2.5 g·kg^{-1} D.M. This is followed by a plateau corresponding to a reduced loss of oil from the soil. The plateau corresponds to the first phenological phases of plant development. The metabolic activity of TPH transformation/reduction has been slow. Note that in the coming months (months of vegetation 12-14) which correspond to the maturity phase of plant development, average monthly loss of TPH was of 12 g·kg^{-1} D.M. The second plateau corresponding to reduced losses of oil products corresponds to reduced metabolic activity installed after the 2nd harvesting, with the coming of autumn. Autumn has reduced the mean rate of loss of TPH in soil to less than 1 g·kg^{-1} D.M. After 16 months, TPH mean loss, in the P1 variant was of 73.3 g·kg^{-1} D.M. Mean residual content of TPH in treated soil was of 7.4 g·kg^{-1} D.M.
4. The presence of quantities of fly ash in the range of 50-250 g/vegetation pot (variants P2 and P3), used in addition to the fertilizing agent, has determined TPH loss in the first 4 months of vegetation of over 60%. This is followed by a plateau corresponding to reduced losses of petroleum products from the soil, up to 2.0 g·kg^{-1} D.M. per month. Autumn has reduced the rate of loss of TPH in soil to<1 g·kg^{-1} D.M. The mean content of residual TPH in soil variants treated with 250 g sewage sludge / vegetation pot and 50-250 g fly ash/pot and cultivated with bird's foot trefoil, was of 3.0 g·kg^{-1} D.M.

In Table 1 are shown the mean quantities of TPH lost from soils of the experimental variants non-cultivated/cultivated with bird's foot trefoil, monitored during 16 months.

Table 1. Mean values of TPH lost from soils of the experimental variants non-cultivated/cultivated with bird's foot trefoil, monitored during 16 months

	Experimental variants				
	P	PO	P1	P 2	P 3
Mean values of TPH ($g\cdot kg^{-1}$ D.M.)	49.7	55.5	73.3	77.5	77.5

4. Conclusions

Maintaining vegetation, under perennial regime specific to the plant, demonstrates plant tolerance to conditions created by the treatment of oil polluted soil with adequate amounts of sewage sludge as fertilizer and fly ash for determining the emergence and development of a culture of leguminous forage plants from the *Lotus corniculatus* species, the bird's foot trefoil. Fly ash addition to variants of oil polluted soil treated with 250 g sewage sludge/vegetation pot, caused a reduction in the content of petroleum products in the soil, in two stages, influenced on the one hand by the stage of plants development and on the other hand by the weather conditions (alternation of seasons). The mean amount of TPH lost during the 16 months of vegetation in soils polluted with 80.5±3.9 $g\cdot kg^{-1}$ D.M. was of 73.3-77.5 $g\cdot kg^{-1}$ D.M. *Lotus corniculatus* species can be used for phytoremediation oil polluted soil with 80.5±3.9 g $TPH\cdot kg^{-1}$ D.M.

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