PETROLEUM-CONTAMINATED SOILS PRICE REGULATION FOR AIDS OF LAND USE OPTIMIZATION AND ECOLOGICAL RISK MITIGATION

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Abstract. The widespread practice involves remediation of petroleum-contaminated soils by an intense usage of microbiological remedies. However, this approach lacks the study of consequences for the soil fertility and other environmental factors. According to our laboratory and field studies, the petroleum-contaminated high-grade soils under certain conditions can be effectively remediated with the increase in fertility and decrease in toxicity. We propose the modification to the land price regulation practice, which will promote the usage of such advantageous remediation techniques, when required. This would result in ecological benefits and sustainable development of the region.

Keywords: ecological risk, petroleum contamination, soil remediation.

Introduction

The problem of soil contamination by oil and petroleum is continuously promoted by shortcomings in production and transportation techniques. Petroleum-contaminated soils (PCS) provide an extremely negative impact on the environment. Indeed, the soil is an essential component of the ecosystem, and the contaminated area usually affects the surrounding territory. The impaired ecosystem causes long-term ecological risks for the land which should not be underestimated. These risks may affect the entire strategy of a region development. For example, the recreation resource of the region will be seriously damped; the food supply security will be contested. The mitigation of ecological risks can be regarded as a kind of ecological insurance. So, the prevention of soil contamination will eventually cost only a few percent of the expenses required for the recovery of damaged ecosystem.

However, the PCS remediation techniques, in their turn, may provide a negative exposure on the ecology [1-3]. This can happen in case of widespread remediation procedure including the PCS flushing by water containing diverse surfactants and biochemical products. For instance, it is important to estimate the consequences for the ecosystem caused by fodder crops cultivation on the PCS remediated by the usage of surfactants of a biochemical origin.

We argue that the risk-based approach including the stimulation of ecologically harmless soil remediation practice is required to ensure the safe environment and sustainable development in the region. We propose to modify the approach to price regulation for the soils affected by petroleum contamination [4]. The goal is to preserve high-grade soils and optimize regional investment projects due to minimization of ecological risks caused by soil contamination. The land users should be economically stimulated in choosing the best practices of soil remediation depending on the soil's role in local environment.

Materials and methods

During laboratory experiments, we studied the changes in bio-productivity of petroleum-contaminated chernozems affected by single flushing with water containing surfactants of the biochemical origin (hydrocarbons and sugar refinement wastes with a fermentation microflora). Prior the flushing, the soil was fertilized with ammonium nitrate, superphosphate and potassium sulfate. Nitrogen, phosphorus and potassium doses were equal to 0.1 $g \cdot kg^{-1}$ of soil. However, during the experiments with clover the mineral nitrogen dosage was 0.03 $g \cdot kg^{-1}$ of soil. The reference soil was fertilized in the same way, but it was not affected by contamination and flushing.

The soil contamination by petroleum was equal to 10 000 $mg \cdot kg^{-1}$ of soil, which is a very high level. The flushing implied a flooding for 5 hours with water solution of sucrose (10 $g \cdot l^{-1}$) and sugar refinement wastes (100 $g \cdot l^{-1}$) containing the fermentation microflora.

The experiment was exhibited into four areas: reference soil, PCS, PCS remediated with flushing, uncontaminated soil with flushing. The following crops were cultivated for two years in each area: oats, barley, corn, clover, lawn grass.

The bioproductivity of soil can be estimated by the crop yield after the first and second years of the experiment, as compared to the reference soil, see Table 1.

Table 1

The crop yield during the experiment

Crops	Type of soil	Average productivity, $kg \cdot m^{-2}$		Changes in productivity, compared to reference, %	
		Year 1	Year 2	Year 1	Year 2
Oats	Reference	0.20	0.10	--	--
	Contaminated	0.10	0.10	-50.0	0.0
	Contaminated + flushing	0.40	0.10	+100.0	0.0
	Uncontaminated + flushing	0.20	0.10	0.0	0.0
Barley	Reference	0.10	0.10	--	--
	Contaminated	0.10	0.20	0.0	+100.0
	Contaminated + flushing	0.02	0.10	-100.0	0.0
	Uncontaminated + flushing	0.20	0.10	+100.0	0.0
Corn	Reference	3.90	0.6	--	--
	Contaminated	0.60	0.9	-85.0	+50.0
	Contaminated + flushing	0.60	1.2	-85.0	+100.0
	Uncontaminated + flushing	3.90	1.1	0.0	+83.0
Clover	Reference	0.20	0.30	--	--
	Contaminated	0.10	0.50	-50.0	+166.6
	Contaminated + flushing	0.10	0.20	-50.0	-33.3
	Uncontaminated + flushing	0.20	0.30	0.0	0.0
Lawn grass	Reference	0.70	0.20	--	--
	Contaminated	0.20	0.60	-74.4	+200.0
	Contaminated + flushing	0.10	0.20	-85.7	0.0
	Uncontaminated + flushing	0.40	0.20	-42.8	0.0

Unfortunately, the weather was significantly different in these two years: dry hot for the first year, and wet cold for the second year. This makes it difficult to investigate the productivity dynamics with time. However, the clear result is that the productivity is substantially diverse for the crop species. It appears that there are species, which demonstrate the yield increase after the remediation procedure. In our case the most positive effect was achieved in case of oats.

The other important factor, which should be taken into account in the remediation practice, is the resulting toxicity of soil. The latter was exposed by its influence on the crop roots growth. The results are presented in Table 2.

Table 2

The remediation aftereffect on soil toxicity

Soil/crop case		Changes in roots growth, compared to reference, %
Oats	Contaminated + flushing	+150.0
	Uncontaminated + flushing	+380.0
Barley	Contaminated + flushing	+25.0
	Uncontaminated + flushing	+35.0
Corn	Contaminated + flushing	-40.0
	Uncontaminated + flushing	+25.0
Clover	Contaminated + flushing	+20.0
	Uncontaminated + flushing	+45.0
Lawn grass	Contaminated + flushing	+15.0
	Uncontaminated + flushing	-50.0

It appears that remediation resulted in significant increase of toxicity when combined with corn and lawn grass planting. Instead, the oats, barley and clover plantations demonstrate a positive effect of remediation by flushing with hydrocarbon water solution containing a fermentation microflora: the resulting soil toxicity significantly decreases.

Results and discussion

We investigated the remediation of petroleum-contaminated chernozems by flushing with hydrocarbon water solution containing a fermentation microflora. The results clearly indicate that the crop species which will be cultivated in subsequent two years should be carefully matched in order to achieve the most positive effect in the yield increase and soil toxicity reduction. For the case explored in the paper, the oats plantation exhibited the best results. After the two-year period, the remediation aftereffects become insignificant if the prior petroleum contamination level did not exceed the value of 10 $g \cdot kg^{-1}$ soil.

Now, as we have established that there ecologically beneficial PCS remediation techniques exist, let us discuss the approach to land price regulations, which may stimulate their usage. In case of land price estimation, the common practice is to regard many factors, but the quality of soils is treated only as their fertility for the agricultural purposes. It is almost ignored that soil is an essential part of the ecosystem. We propose to consider the quality of soils as an ecological benefit, which mitigates the risks for the overall region development strategy including diverse investment projects. Consequently, the land price regulation practice should target the following goals:

- protection of high-grade soils for the sake of ecological and food supply safety;
- optimization of investment projects and mitigation of risks for the region's development.

The first goal can be achieved by discounting the cost of lands with high-grade soils contaminated by petroleum, in case when the lands are used for agricultural purposes. The discount value should be equal to an appropriate cost of the effective remediation procedure. This will motivate the customers and land users to execute the remediation of PCS instead of abandoning the polluted lands. As a result, the high-grade soils will be preserved, providing a sustainable ecosystem in the region. And the maintenance of their agricultural usage will promote the region's food supply safety.

The second objective can be implemented if one counts the average risk of land pollution by petroleum during the current (or expected in near future) economic activity in the region. The lands at risk zone which do possess high-grade soils should also be discounted and transferred (if possible) into the category of lands intended for agricultural usage. As we have shown, the intense agricultural usage with a correct remediation technique will result in fast purification of the polluted area and preservation of the environment. The land discount value (per ha) can be estimated by the formula:

$$D = < P > / < C >,$$

where D – discount value, per ha;
$<P>$ – average cost of PCS remediation, per ha;
$<C>$ – average cost of lands in risk zone, per ha.

Although the society will bear the costs of the discounting, the ecological benefits will definitely result in economical ones.

The remediation of lands with low-grade soils can hardly be performed with preservation of the ecosystem. Therefore, it is advisable to transfer these lands into categories, which imply the decay of the land ecosystem during the usage. Then petroleum contamination will have a minor effect.

Conclusions

1. An effective remediation technique for high-grade petroleum-contaminated soils is presented.
2. The land price regulation practice leading to ecological risks mitigation and land use optimization in case of the existing or possible land pollution by petroleum is proposed.

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