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Technology of Evaluation Methods of Soil Remediation Effectiveness According to Biological Indicators

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Abstract: To evaluate effectiveness of remediation of soils polluted with crude oil or oil products it may be recommended to use the technology of determination of integral indicator of biological state (IIBS) of the soil. It is determined according to the most informative biological indicators. When IIBS of remediated soil and IIBS of unpolluted soil differ not more that by 10% the remediation has been made correctly. If the difference is more that 10% the remediation did not achieve the designed goal. When the difference between IIBS of polluted and clear soil is less than 10% before remediation it is not reasonable to carry it out. Proposed technology was tested on "Maykop landfill". Remediation of compact chernozem of "Maykop landfill" may be considered effective because the difference between IIBS of unpolluted and polluted soils was 30% before remediation and only 5% after remediation. Technical step of remediation of brown forest soils should not be done because upper humus layer of the soil has been moved away together with fuel oil and IIBS was dramatically reduced. Before remediation the difference between IIBD of polluted and clear soils was only 12% so it would have been more reasonable to limit the works to biological remediation.

Key words: Ecobiotechnology · Soil pollution · Fuel oil · Remediation · Effectiveness · Biological indicators · Catalase activities · Dehydrogenase activities · Number of bacteria of the *Azotobacter* genus · Phytotoxic of soil

INTRODUCTION

Soils polluted with oil and oil products require remediation. Still before remediation it is necessary to evaluate if it will be reasonable or not. After remediation it is reasonable to evaluate the results.

It may be done with such an indicator as residual oil and oil products in soil. But it is not indicative of actual state and functioning of the soil because the same residual oil and oil products in some soils (less resilient to pollution) causes deterioration of ecosystem functions of that soil while in the other soils (more resilient to pollution) it does not affect normal functioning.

Integral indicator of biological state (IIBS) determined according to the most informative biological indicators [1-3] is a more accurate indicator of deterioration of soil environmental functions as a result of chemical pollution. Biological indicators are highly sensitive and are the first to indicate the deviation in normal state of soil and its functioning [4-13]. Previously it was determined that environmental functions of a soil are normal if IIBS decrease less than 5%, information environmental functions are deteriorated when IIBS goes lower than 5-10%, biochemical, physicochemical, chemical and integral functions are deteriorated when IIBS is lower than 10-25 %, physical-lower than 25% [14].

Near the city of Maykop there is one of the largest areas of fuel oil pollution. Condensate with fuel oil and periodically the fuel oil have been discharged from boiler house for a long time that led to catastrophic pollution of the territory. While the environmental affect was negative the territory became the valuable testing ground for studying the implications of fuel oil pollution of soils and environmental systems in natural conditions and adjustment of the ways to eliminate the fuel oil pollution [15-18].

The goal was to develop and test evaluation method for effectiveness of remediation of soils polluted by fuel oil according to biological indicators.

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Methods: The territory of research is located in Maykop region in Respublika Adygeya. The source of pollution is boiling house where it is used low-ash (ash content not more that 0,14%) furnace fuel oil 100, type IV, sulphur mass fraction not more than 2% with chill point not more than minus 25°C.

Soil covering consists of two types of soils: upper half of the slope-leached compact chernozem, lower half of the slope-brown forest low unsaturated soil. Typical vegetation of the territory-beech, oak, hornbeam forest with dead cover. Polluted territory is crossed by the cutting that have been overgrown with herbaceous vegetation.

In 2008 the territory of "Maykop landfill" was remediated. Technical remediation-removing fuel oil from soil surface in places if necessary with upper layer of soil impregnated with fuel oil was done in summer. Biological remediation was carried out in autumn and consists of ploughing up the areas left without vegetation in the first step of remediation and sowing them with winter wheat.

Soil samples were taken before remediation (2007) after technical step (2008) and biological step (2009) of remediation.

Samples were taken both from unpolluted areas and from areas with different states of pollution with fuel oil. 9 soil samples from upper layer of leached compact chernozem have been taken from each of 3 areas (unpolluted, low pollution, heavy pollution) during three years (2007-2009); samples of brown forest low unsaturated soil have been taken according the same scheme.

Laboratory and analytic research was carried out in the Department of Ecology and Nature Management of Southern Federal University on the base of conventional procedures [19, 20]. Catalase activity was measured by Galstyan method, dehydrogenase activity-by Galstyan method in Khaziev modification. Number of bacterium was determined by luminous microscopic method, number of *Azotobacter* bacterium by the method of blob fouling on Ashby medium. Phytotoxic was evaluated by changes in indicators of seeds germination (germinating capacity, germinative energy, germinative harmony, germination rate) and the intensity of initial growth of a plant. Garden radish (Corundum breed) was used as test object.

Humus content was determined by Turin method with spectrophotometric ending. Soil reaction (pH) was determined by potentiometric method.

Integral indicator of biological state (IIBS) of the soil was determined according the most informative biological indicators: catalase activity, dehydrogenase activity, number of *Azotobacter* bacterium and germinating capacity. *Azotobacter* bacterium is traditionally used as an indicator of chemical pollution of soil. Catalase and dehydrogenase are indicative of the development of redox processes. They belong to oxidoreductases that are more sensitive to chemical pollution. Germinating capacity allows making conclusions about the conditions of plants growing.

To determine IIBS the value of each indicator of control sample (unpolluted soil) was taken as 100% and the values obtained in the other variants of test (polluted soil) were evaluated as percentage of this value. Then the average of all six indicators was calculated for each variant. The resulted value (IIBS) was evaluated as percentage of control value (100%). The method used allows integrating (aggregating) the relative values of different indicators, when absolute values of these indicators cannot be summed up due to different measures.

RESULTS

Table 1 provides the content of fuel oil in unpolluted, low polluted and heavy polluted soils of "Maykop landfill".

Table 2 provides the integral indicator of biological state (IIBS) determined according the most informative biological indicators catalase activity, dehydrogenase activity, number of *Azotobacter* bacterium and germinating capacity of garden radish.

As it may be concluded from table 2 technical step of remediation did not affect the state of compact chernozem (IIBS deacrease till 70% before remediation, after-69%) and dramatically decreased the indicators of brown soil (IIBS before remediation-88%, after-78%). It is explained by the fact that together with fuel oil it was removed also upper level of brown soil with the main content of humus. In chernozem the humus is distributed by soil profile more regularly so IIBS almost did not decrease.

Biological step of remediation increased IIBS in compact chernozem from 69 % to 95 % of IIBS of clear soil and in brown forest soil from 78 % to 82 %.

As a result of doth steps of remediation IIBS of compact chernozem increased from 70% to 95% of background and IIBS of brown forest soil decreased from 88% to 82%.

Table 1: Oil product content in upper level of "Maykop landfill" soil (0-10 sm)

Fuel oil content	unpolluted	Low pollution	Heavy pollution
Compact chernozem			
visually	no fuel oil	sparse spots as an incrustation of dried fuel oil up to 1 sm on soil surface	continuous layer of newly discharged fuel oil up to 2 sm on soil surface
mg/g	0,13	0,26	0,32
%	0,013	0,026	0,032
Brown forest soil			
visually	no fuel oil	sparse spots as an incrustation of dried fuel oil up to 1 sm on soil surface	continuous layer of newly discharged fuel oil up to 2 sm on soil surface
mg/g	0,14	0,18	0,21
%	0,014	0,018	0,021

Table 2: Changing of IIBS* of the soils of "Maykop landfill" after remediation, %

	Non-rehabilitated area		Rehabilitated area			
Year	unpolluted	Pollution (insignificant**) remains	Remediation steps	Pollution (heavy**) eliminated	*Difference between 1 and 2*	*Difference between 1 and 3*
	1	2		3		
Compact chernozem						
2007	100	95	Before remediation	70	-5	-30
2008	100	101	After technical remediation	69	1	-31
2009	100	106	After biological remediation	95	6	-5
Brown Forest soil						
2007	100	118	Before remediation	88	18	-12
2008	100	116	After technical remediation	78	16	-22
2009	100	113	After biological remediation	82	13	-18

Note: * IIBS determined according to indicators: catalase activity, dehydrogenase activity, number of *Azotobacter* bacterium and germinating capacity of garden radish; **

In the areas with low initial pollution that were not rehabilitated IIBS of compact chernozem increased from 95% to 106% and IIBS of brown forest soil insignificantly decreased from 118% to 113%. It is indicative from one hand of stimulating effect of low doses of fuel oil and from the other hand on the fact the decision not to rehabilitate areas with low pollution was right.

In [14, 21] it is shown that decrease of IIBS of soil more than 10% leads to deterioration of important environmental functions of soil.

So, when IIBS of rehabilitated soil and IIBS of unpolluted soil differ not more that 10% the remediation has been made correctly. If the difference is more that 10% the remediation did not achieve the designed goals.

When the difference between IIBS of polluted and unpolluted soil is less than 10% before remediation it is not reasonable to carry our remediation because it requires expenditure and the effect is not significant because the soil fulfills the main environmental functions without remediation.

As Table 2 shows remediation of compact chernozem may be considered effective because the difference between and polluted soil was 30% before remediation and only 5%-after it, that is less than 10%.

As for remediation of brown forest soil the technical step was unreasonable. In this step the upper humus layer of the soil had been moved away together with fuel oil. As Table 2 shows this process practically didn't affect IIBD of compact chernozem (70% before, 69% after) because lower layer of this soil is also rich ho humus but it dramatically decreased IIBS of brown forest soil (88% before, 78% after). Biological step of remediation slightly increased the IIBS of this soil (82% from background) but did not recover even the values of the state before remediation (88%).

Before remediation IIBS of polluted brown forest soil differ from IIBS of unpolluted soil only for 12%. This soil was lower polluted than chernozem. As 12% is close to 10% it would have been more reasonable to make only biological remediation especially taking into the account genetic characteristics of this soil-high humus content in upper level of the soil.

CONCLUSION

To evaluate effectiveness of remediation of soils polluted with crude oil or oil products it may be recommended to use the technology of determination of integral indicator of biological state (IIBS) of the soil determined according to the most informative biological indicators. When IIBS of rehabilitated soil and IIBS of unpolluted soil differ not more that by 10% the remediation has been made correctly. If the difference is more that 10% the remediation did not achieve the designed goal. When the difference between IIBS of polluted and unpolluted soil is less than 10% before remediation it is not reasonable to carry our remediation.

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