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Simulation of Ordinary Chernozem Pollution by Heavy Oil to Determine Environmentally Safe Concentrations

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Abstract: The consequences of soil pollution by oil are more or less explored. Though in the meantime there are almost no publications devoted to the effect of heavy oil on soil properties, whereas pollution of soil by heavy oil is not such a rare occurrence. The purpose of the present study was to determine the environmentally safe concentration of the heavy oil in the ordinary chernozem based on biological indicators obtained through the simulation experiment. Chernozem is the most fertile soil in the world and plays a significant role in the provision of ecological and food safety of mankind. As a result of study, it was found that the pollution of the common mould humus by heavy oil causes deterioration of soil biological properties. This leads to a reduction in catalase and dehydrogenase activities, cellulolytic ability, abundance of the *Azotobacter* genus bacteria, the rates of germination and initial growth of plants. Generally, the damage factor is directly dependent on the amount of heavy oil in the soil. Ordinary chernozem is relatively resistant to pollution by heavy oil because of its ecological and genetic properties, such as good structure index, oxidizing conditions and high biological activity. Environmentally safe concentration of heavy oil for common mould humus is 0.7 %.

Key words: Simulation · Pollution · Heavy oil · Ordinary chernozem · Biological indicators · Catalase activity · Dehydrogenase activity · Cellulolytic activity · Abundance of the Azotobacter genus bacteria · Soil phytotoxicity · Environmentally safe concentrations

INTRODUCTION

Chernozem is the most fertile soil in the world and play a significant role in the provision of ecological and food safety of mankind. At the same time, they are exposed to significant anthropogenic pressure, in particular pollution by oil and oil products.

The consequences of soil pollution by oil are more or less explored [1-4]. Also, in the literature there is evidence on the effects on soil properties of gasoline, diesel fuel, kerosene [4-7], polycyclic aromatic hydrocarbons (PAHs), fluorene and benzapyren, polychlorinated biphenyls [8,9], the fuel oil [10] and oil oxidation products [11]. Though in the meantime there are almost no publications devoted to the effect of heavy oil on soil properties, whereas pollution of soil by heavy oil is not such a rare occurrence. The sources of pollution are the sites of heavy oil storage, transportation and use, in particular, prevailing boiler houses running on heavy oil.

The purpose of the present study was to determine the environmentally safe concentration of the heavy oil in the ordinary chernozem based on biological indicators obtained through the simulation experiment.

MATERIALS AND METHODS

Sampling of soil for simulation studies was carried out in the Oktyabrskiy district of Rostov region. The soils were rich in humus - 7.4%, had neutral pH - 7.9, heavy grain size distribution and high biological activity.

The soil sampling for the simulation experiments was carried out from the top 20 cm ground layer where the main amount of polluting substances is accumulated and their negative impact on soil is the most essential.

The following heavy oil concentrations were studied: 0.1, 0.5, 1.0, 2.5, 5, 10, 25 and 50% by soil weight. During the simulation experiment, the heavy oil was added in moist soil simulating its surface pollution. When carrying

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out the simulation experiments, plastic cups were used as containers for composting soil. Soil mass in the container was 1 kg expressed in terms of the air-dry soil. Packing of the containers with soil was performed in accordance with generally accepted methods of greenhouse trials.

The soil was incubated in the vegetation vessels at room temperature (20-22°C) and the optimal humidification (60% of normal field capacity) in threefold repetition.

Soil status was determined after 30 days from the day of pollution. This term is the most informative when evaluating oil pollution of soil [5].

Employing the techniques conventional in soil biology [12, 13], authors estimated the abundance of *Azotobacter* genus bacteria, catalase, dehydrogenase and cellulolytic activities and germination ability of radish seeds. The *Azotobacter* genus bacteria are conventionally and successfully used as an indicator of the soil chemical pollution. Catalase, dehydrogenase and cellulolytic activities show the intensity of a variety of biological processes in the soil. At that, the enzyme strength is a measure of the potential biological activity of the soil, while the decay rate of soil bed characterizes the current activity. Catalase and dehydrogenase belong to redox enzymes which are most sensitive to chemical pollution. Germination, length of roots and aerial parts of radish indicate the phytotoxic properties of chemically polluted soil. Thus, the presented set of indicators provides an objective and informative picture of the biological processes taking place in the soil and its environmental status as a whole.

To combine the different biological indicators, authors have used the special technique to determine the integral indicator of the soil biological condition (IISBC) [14].

Statistical processing of data was performed using analysis of variance followed by determining the least significant difference (LSD), as well as correlation and regression analyses. Mathematical treatment of the results was carried out using "Statistica 6.0" computer software code.

RESULTS

Research data on the biological properties of ordinary chernozem polluted by heavy oil are presented in Table 1. As is obvious from the table, all the studied biological indicators (catalase and dehydrogenase activity, cellulolytic ability, abundance of the *Azotobacter* genus bacteria, the rates of germination and initial growth of plants) of common mould humus polluted by heavy oil are reduced.

Integral indicator of the soil biological condition (IISBC) was determined based on above investigated indicators (Fig. 1).

According to research by S.I. Kolesnikov *et al*. [15], a significant change of the soil ecological functions does not occur until the IISBC values decreased by more than 10%. Reduction of IISBC values by more than 10% indicates a violation of the basic ecological functions of the soil in terrestrial ecosystems, such as the accumulation and transformation of matter and energy, sanitary function, the buffer and the protective biogeocenotic screen, the existence and evolution conditions of organisms [15].

Reducing of IISBC of ordinary chernozems by more than 10% is found out at a concentration of heavy oil in the soil higher than 0.7% (Fig. 1). Accordingly, a lower content of heavy oil in the ordinary chernozems can be considered environmentally compatible.

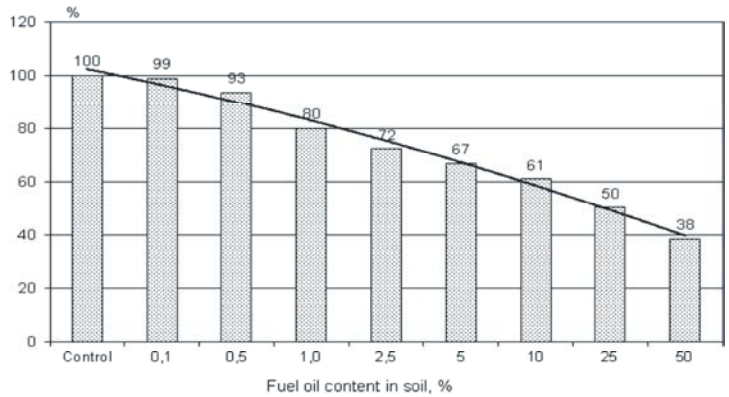

Fig. 1: Variation in the integral indicator of the biological condition (IISBC) of the ordinary chernozem polluted with heavy oil, % of control value.

Table 1: The influence of heavy oil pollution on environmental and biological properties of ordinary chernozem

Content of heavy oil in soil, %	Catalase activity ml O_2/g	Dehydro-genase activity mg TTX/10 g	Cellulolytic activity, %	Germi-nation %	Roots length, %	Shoots length, %	Abundance of *Azotobacter* genus bacteria, flocculation %
Control	9.4	15.4	100	100	100	100	100
0.1	8.5	14.7	100	98	87	79	84
0.5	6.9	12.8	99	96	83	61	70
1	6.2	11.9	77	78	43	49	64
2.5	4.5	11.4	65	71	51	53	58
5	4.1	10.3	49	67	35	32	45
10	3.4	9.9	38	62	33	30	32
25	3.0	8.3	0	60	58	55	21
50	2.4	1.5	0	54	37	40	12
HCP_{05}	0.4	1.8	20	9	6	6	5

The results of the present study were compared with the results obtained previously for other soils in the Southern Russia, specifically compact leached mould humus, brown forest soils and grey sands [16-21]. It was found that ordinary chernozem is more resistant to pollution by heavy oil. This is determined by its ecological and genetic properties, such as good structure index, oxidizing conditions, high absorbability and high biological activity.

CONCLUSION

Pollution by heavy oil causes deterioration of the biological properties of the ordinary chernozem. This leads to a reduction in catalase and dehydrogenase activities, cellulolytic ability, abundance of the *Azotobacter* genus bacteria, the rates of germination and initial growth of plants. Generally, the damage factor is directly dependent on the amount of heavy oil in the soil.

Ordinary chernozem is relatively resistant to pollution by heavy oil that is determined by their ecological and genetic properties, such as good structure index, oxidizing conditions and high biological activity.

Environmentally safe concentration of heavy oil for common mould humus is 0.7%.

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