Determination of toxicity of soil contaminated with by of petrochemical hidrocarbons

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Abstract. This work presents the results of experimental studies of the effect of the distillation residue of petrochemical industry containing heavy hydrocarbons on soil toxicity using phytotesting methods. Spring wheat «Omskaya-36» seeds were used as a test object. The experiments were conducted according to the certified method for determining soil toxicity by seed germination and measuring the average length of watercress seedlings (Lepidium sativum) FR.1.39.2016.24117. The studies were conducted in laboratory conditions for three types of soil: gray forest, sod-podzolic, leached chernozem. The assessment was determined by such parameters as seed germination, underground, aboveground and the total seedling length. The studies revealed a negative effect of the petrochemical distillation residue on the studied soil types. The results showed the effectiveness of using Lepidium sativum to determine the toxicity of the analyzed soils containing toxic hydrocarbons. The developed method can be used for the analysis of the pollutants toxic effect on soils.

1. Introduction

One of the main environmental problems is soil pollution with oil and oil products, which negatively affects the physical, morphological and agrotechnical properties of soils. Therefore, research on the development and improvement of methods for testing the state and properties of contaminated soils is relevant [1-5]. In particular, contact biotesting methods are widely used. In such methods the test object directly interacts with contaminated soil [6-10].

This work presents the results of experimental studies of the influence of the distillation residue of petrochemical industries containing heavy hydrocarbons on soil toxicity using phytotesting methods.

2. Practical part

Distillation residue is a homogeneous liquid (the color is from light brown to dark brown). It is a waste obtained in the production of subtansies such as agidol and absorbents of various grades, containing heavy hydrocarbons from C6 and higher. The distillation residue is used together with fuel oil or another type of fuel to reduce the viscosity and accelerate the kindling. Heating plants operating leads to environmental pollution. It pollute atmosphere by toxic products of fuel combustion, such as oxides of sulfur, soot, nitrogen and carbon oxides and also soil - during storage and transportation of fuel. The main physical and chemical properties of the distillation residue are shown in the table 1.
Table 1. Physico-chemical properties of petrochemical distillation residue.

| Name of the determined parameter                  | Measurement result |
|---------------------------------------------------|--------------------|
| mass fraction of water (%)                        | -                  |
| mass fraction of sulfur (%)                       | 0.786              |
| flash point in a closed crucible (°C)             | 97                 |
| flash point in an open crucible (°C)              | 171                |
| viscosity at 50°C                                 | 68.52              |

Seeds of spring wheat of variety "Omskaya-36" were used as a test object. The choice of this plant is due to the intensive and high seeds germination, which are noticeably reduced in the presence of contaminants. The experiments were carried out using a certified method FR.1.39.2016.24117 [5]. The studies were carried out in laboratory conditions for each of the following types of soils: gray forest, sod-podzolic and leached chernozem parallelly. Physicochemical characteristics of soils are presented in table 2.

Table 2. Physico-chemical characteristics of soil.

| Analyzed parameters                  | Leached chernozem | Gray forest | Sod-podzolic |
|-------------------------------------|-------------------|-------------|--------------|
| humus content (%)                   | 5.4               | 4.3         | 1.8          |
| the amount of absorbed bases (mg-eq / 100 g) | 54.2             | 9.3         | 12.2         |
| pH of the salt extract of soil      | 6.6               | 3.5         | 3.9          |
| pH of water extract of soil         | 7.8               | 4.8         | 5.5          |

150 g of the studied soils were placed into plastic cups and were contaminated with distillation residues with mass fractions of 0.25%, 0.5%, 1%, 2%, 5%. Uncontaminated soil of the corresponding type was used as a control. The experiments were carried out for three times. 20 seeds of wheat of the variety "Omskaya - 36" were planted into each cup with soil to a depth of 1 cm. Then 60 ml of distilled water were poured. On the seventh day after the start of the experiment, the germination of seeds (%), underground, aboveground and total seedling parts length (mm) were measured. Statistical data were processed using the Statistica 5.0 software.

In the sample with the maximum amount of toxicant (5.0%), the highest germination of wheat seeds (25.0%) was observed in gray forest soil with a humus content of 4.3%, the lowest (6.7%) - in leached chernozem with humus content of 5.4%. The seeds germination in the sample with the gray forest soil and soddy-podzolic soil with the minimum toxicant content (0.25%) was more than 90.0%, in the sample with leached chernozem, the germination of wheat seeds was 85.0%.

Seed germination increases with a decrease in the concentration of the pollutant, which indicates the toxic effect In all analyzed samples. The greatest deviation of the native sample from the control was in leached chernozem (92.4%), the least - in gray forest (73.2%) and in soddy-podzolic (88.3%). The experimental error in some cases reached 17.6%.

A similar dependence was in all analyzed samples for the average length of underground seedling parts. This parameter increases with a decrease in the toxicant content in the soil (table 3). However, in contrast to germination, the maximum length of the underground seedling part was observed in the soil with the highest humus content – leached chernozem (5.2 mm). The smallest length of seedlings was on gray forest soil (2.0 mm) with humus content 4.3%.

The deviation of the sample containing 5% of the distillation residue from the control in the gray forest soil and soddy-podzolic soil is 98.0%, in leached chernozem – 95.0%. It indicates the negative effect of the studied toxicant on the plants root system. The experimental error was 6.0%
Table 3. The average length of seedlings underground parts of wheat variety «Omskaya 36».

| Toxicant content in soil (%) | Length(mm) | Standardmistake |
|-----------------------------|------------|-----------------|
| Leached chernozem            |            |                 |
| 5                           | 5.22       | 5.49            |
| 2                           | 19.48      | 2.42            |
| 1                           | 45.49      | 2.54            |
| 0.5                         | 64.63      | 3.65            |
| 0.25                        | 86.51      | 4.93            |
| control                     | 103.56     | 4.62            |
| Gray forest soil            |            |                 |
| 5                           | 2.00       | 1.76            |
| 2                           | 16.58      | 3.36            |
| 1                           | 34.83      | 4.13            |
| 0.5                         | 66.97      | 6.30            |
| 0.25                        | 88.19      | 5.38            |
| control                     | 106.05     | 4.31            |
| Sod-podzolic soil           |            |                 |
| 5                           | 3.11       | 0.63            |
| 2                           | 5.95       | 1.07            |
| 1                           | 15.87      | 2.07            |
| 0.5                         | 83.05      | 6.21            |
| 0.25                        | 91.35      | 6.82            |
| control                     | 136.17     | 7.28            |

The petrochemical distillation residue negatively affects the underground part (root) of the seedling also. It suppresses its growth with a decrease in the concentration of the toxicant (table 4). The average length of the aboveground seedlings part of the is minimal in leached chernozem - 6.0 mm, in gray forest soil and in soddy-podzolic soil it is practically the same and equal to 7.3 mm and 7.6 mm, respectively. The deviation of the values in the samples with native soil from the control for leached chernozem is 92.6%; for gray forest and soddy-podzolic soil is 93.0%. The experimental error is 8.0%.

Table 4. The average length of seedlings aboveground parts of wheat "Omskaya 36".

| Toxicant content in soil (%) | Length(mm) | Standardmistake |
|-----------------------------|------------|-----------------|
| Leached chernozem            |            |                 |
| 5                           | 6.06       | 1.92            |
| 2                           | 13.84      | 2.38            |
| 1                           | 37.14      | 4.31            |
| 0.5                         | 53.17      | 5.68            |
| 0.25                        | 77.26      | 5.68            |
| control                     | 81.65      | 5.94            |
| Gray forest soil            |            |                 |
| 5                           | 7.27       | 2.98            |
| 2                           | 20.50      | 3.68            |
| 1                           | 43.79      | 6.54            |
The dependence of the total length of the seedling on the content of the toxic substance in the soil is similar to the average germination of seeds, the average length of the underground and aboveground parts of the seedlings, which confirms the negative impact of the vat residue on plants (table 5). The maximum length in leached chernozem is practically equal to that in the sample with sod-podzolic soil and is 10.4 mm and 10.6 mm, respectively. The deviation of the values of the native soil sample from the control is 94.4% for leached chernozem, and 95.6% for forest and soddy-podzolic soil. Experimental error is 13.9%.

**Table 5.** The average total length of seedlings of wheat variety «Omskaya 36».

| Toxicant content in soil (%) | Length (mm) | Standardmistake |
|-----------------------------|-------------|-----------------|
| **Leached chernozem**       |             |                 |
| 5                           | 10.44       | 5.56            |
| 2                           | 33.31       | 4.45            |
| 1                           | 82.63       | 6.10            |
| 0.5                         | 117.80      | 8.89            |
| 0.25                        | 163.77      | 9.38            |
| control                     | 185.21      | 9.34            |
| **Gray forest soil**        |             |                 |
| 5                           | 9.27        | 4.51            |
| 2                           | 37.07       | 6.55            |
| 1                           | 78.62       | 9.88            |
| 0.5                         | 134.70      | 13.17           |
| 0.25                        | 168.15      | 11.19           |
| control                     | 211.38      | 10.71           |
| **Sod-podzolic soil**       |             |                 |
| 5                           | 10.67       | 5.67            |
| 2                           | 25.57       | 5.35            |
| 1                           | 56.81       | 7.13            |
| 0.5                         | 160.22      | 12.75           |
| 0.25                        | 172.54      | 13.91           |
| control                     | 245.78      | 13.94           |

The dependence of the analyzed parameters on the dilution ratio is presented in table 6. A negative reliable dependence of the main parameters on the content of the residue was revealed in all samples. This dependence shows the toxic effect of the studied toxicant in the soil on the plant.
Table 6. The dependence of the analyzed parameters on the concentration.

| Soil type                      | Correlation coefficient | Regression equation       | Safe dilution ratio |
|-------------------------------|-------------------------|----------------------------|---------------------|
| Seedling germination (%)      |                         |                            |                     |
| leached chernozem             | -0.933                  | $X = 94.757 - 17.19^a Y$   | 5.1                 |
| gray forest soil              | -0.911                  | $X = 98.937 - 14.25^a Y$   | 5.2                 |
| sod-podzolic soil             | -0.915                  | $X = 100.55 - 18.03^a Y$   | 5.0                 |
| The length of the seedling underground part of the (mm) |                         |                            |                     |
| leached chernozem             | -0.864^a                | $X = 70.261 - 14.86^a Y$   | 4.4                 |
| gray forest soil              | -0.836                  | $X = 68.717 - 15.43^a Y$   | 3.2                 |
| sod-podzolic soil             | -0.661                  | $X = 67.997 - 16.08^a Y$   | 4.0                 |
| The length of the aboveground part of the seedling (mm) |                         |                            |                     |
| leached chernozem             | -0.815                  | $X = 59.317 - 12.47^a Y$   | 4.3                 |
| gray forest soil              | -0.872                  | $X = 68.196 - 13.91^a Y$   | 4.4                 |
| sod-podzolic soil             | -0.795                  | $X = 70.906 - 14.63^a Y$   | 4.3                 |
| Seedling total length (mm)    |                         |                            |                     |
| leached chernozem             | -0.845                  | $X = 129.73 - 27.51^a Y$   | 4.3                 |
| gray forest soil              | -0.857                  | $X = 136.91 - 29.34^a Y$   | 4.3                 |
| sod-podzolic soil             | -0.727                  | $X = 138.90 - 30.71^a Y$   | 4.2                 |

*a Reliable correlation coefficients. X is the analyzed parameter. Y is dilution ratio.

The safe dilution ratio (when the length of seedlings in toxic soil will be equal to the length in the control clean soil, which was calculated by the regression equation) for the average underground, aboveground and total seedling length was on average 4.4 and for seed germination was 5.1.

The leached chernozem with 5% of distillation residue had less toxicity to plants, which is explained by the increased humus content in comparison with other analyzed soils. However, seed germination is more sensitive to the toxicant in leached chernozem (pH = 6.6) and less in gray forest soil (pH = 3.5), which is due to different soil acidity.

3. Conclusion
The carried out researches revealed the negative influence of the residue on the studied soils.

The results showed the effectiveness of using wheat seeds to determine the toxicity of the analyzed soils containing toxic hydrocarbons. So, the researched biotesting method can be used to analyze the toxic effect of other pollutants on soils.

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