

The Usage of Plant Test Systems for the Determination of Phytotoxicity of Contaminated with Petroleum Products Soil

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ABSTRACT

The level of phytotoxicity of the soil samples artificially contaminated with the aviation kerosene was determined in the work. The dependences of the growth characteristics of the plant test system (flax) on the excess of the approximate permissible concentrations (APC) of the oil product concentration in the soil were identified. The change in the mass of raw material depending on the level of aviation kerosene contamination of soil samples was determined. A decrease in the plant growth activity with an increase in the content of aviation fuel in the soil was established. It was found that there is a hormesis effect at certain concentrations of aviation kerosene in the soil. The comparison of the concentration dependences of the action of petroleum products on the growth rates of seedlings and their dependence on the distance to the source of pollution allowed in the latter case to conduct a kind of “dosimetry” on exposure concentrations when the petroleum product concentration was not determined.

Keywords: phytotoxicity, biotesting, soils, oil products, pollution, aviation fuels.

INTRODUCTION

Nowadays, the degradation of vegetation and surface layer of soil caused by human activities is one of the most important environmental problems. Vegetation and soil are powerful biochemical barriers that can accumulate pollutants from a variety of sources. The activities of modern aviation enterprises, in particular airports, are accompanied by a man-made load on all components of the environment. Soil is one of the components of ecosystems which is most sensitive to human activities [Adebiyi, 2011, Franchuk, 2005, Lapinskiene, 2006, Radomska, 2020]. It is necessary to take into account the negative impact of anthropogenic factors on soils, in particular, the destruction of balanced natural ecological relationships in the soil, the undesirable process of gum-mine mineralization, increasing acidity or alkalinity of soils, as well as the recovery process [Yanovsky, 2016]. In extreme cases, there is a local destruction of soil cover in the territories of aviation

enterprises and adjacent territories. Heavy metals, petroleum products and other chemicals are becoming more common soil contaminants leading to the formation of artificial deserts near airports and causing erosion [Madzhd, 2018].

In off-road areas, about 50% of particulate matter emissions during aircraft take-off are distributed in the areas near airports. Accumulation of pollutants on roads can cause ecosystem pollution and make the soil of adjacent areas unsuitable for the agricultural use [Groza, 2010].

The soil near the airports is contaminated with heavy metal salts and organic compounds within a radius of 2–2.5 km. In the autumn, winter and spring periods, the anti-ice treatment of air transport as well as removal of snow and ice deposits from the artificial surface of airfields is carried out. It uses active anti-ice preparations and reagents containing urea, ammonium nitrate, and surfactants that also infiltrate into the soil [Cruz, 2013, Madzhd, 2020].

Compared to the atmosphere or water, soil is a less dynamic and more buffer system. One of the characteristics of the soil is that it accumulates the information about the processes and changes that occurred, so it can not only indicate the state of the environment at a certain time, but also reflect past processes. Soil has a protective function and can be a major source of many chemicals that contaminate surface and groundwater and pose a danger to plants [Adebiyi, 2011, Cherniak, 2018, Cherniak, 2019, Cherniak, 2017].

The impact of oil pollution on plants occurs in two ways: directly through the receipt of oil components by the root and foliar route and their inclusion in metabolism; and indirectly through the changes in the physical and chemical composition of the soil and violations of its biological characteristics. The components of the liquid part of petroleum products enter the plant body through the root system, which can cause mutagenic reactions or deviations from normal development in morphological parameters [Moebius, 2007, Salvatore, 2008, Vasilyev, 2012].

Soil phytotoxicity is a general indicator that can be used to characterize the effect of soil on higher plants.

If there are toxic substances in the soil, they can affect seed germination or plant development. One of the main criteria for soil toxicity is the assessment of the dynamics of seed germination and the number of germinated seeds over a period of time [Bogolyubov, 2010, Grodzinsky, 2006, Plaza, 2005].

Phytotesting is based on the sensitivity of plants to the exogenous effects of chemical substances, which is reflected in growth and morphological characteristics. The main requirements of the method are: expressiveness, convenience and simplicity of experiments, repeatability and reliability of results, economy and objectivity [Evdokimov, 2012, Mann, 2019].

In order to detect the toxicity of soil and aquatic environment, phytotests are used, in which plants are able to respond to exogenous chemical effects, which are fixed by the parameters of seed germination, growth rate of roots and shoots, i.e. act as indicators of soil toxicity [Cherniak, 2017].

The aim of the study was to determine the phytotoxicity of soil samples artificially contaminated with aviation fuel using a plant bioassay with flax (*Linum usitatissimum L.*).

MATERIAL AND METHODS

The soil mixture, the characteristics of which is given in Table 1, was divided into five plants, 200 g of soil was added to each of them.

Aviation kerosene brand TS-1 was added to the four soil samples in a concentration multiple of the standard APC of the content of petroleum products in the soil according to the weight of the soil sample (200 g) selected for the study, namely:

- I – soil without the addition of aviation kerosene (control);
- II – 1 APC (0.04 g of aviation kerosene);
- III – 10 APC (0.4 g of aviation kerosene);
- IV – 100 APC (4 g of aviation kerosene);
- V – 1000 APC (40 g of aviation kerosene).

After that, 272 flax seeds were sown in each of the five plants. The plants were placed in a plastic bag and placed in a thermostat with the constant lighting at a temperature of 23°C (Fig. 1).

The lengths of roots and stems of seedlings were measured on the 3rd, 5th and 7th days of seed germination.

RESULTS AND DISCUSSION

Figure 4–5 show the dependences of the length of the stem and root of flax seedlings on the time of germination. In turn, Figure 6 presents the dependence of the raw mass of seedlings on the concentration of petroleum product in the studied soil samples.

Analysis of the results shown in Figure 4, gives grounds to assert that on the third day of incubation of flax on a soil sample with the content of oil product 1 APC, the plant growth was

Table 1. Characteristics of the soil mixture

Characteristic	Indicator
Mass fraction of organic matter, %, not less	70
Ash content, %, no more	30
Mass fraction of nitrate nitrogen, mg/100g, not less	12
pH, units	5.0 – 7.0
Mass fraction of ammonium nitrogen, mg/100g, not less	3
Mass fraction of mobile phosphorus (P ₂ O ₅), mg/100g, not less	15
Mass fraction of mobile potassium (K ₂ O), mg/100g, not less	20
Composition	peat, lowland peat



Figure 1. Placement of soil samples in the thermostat

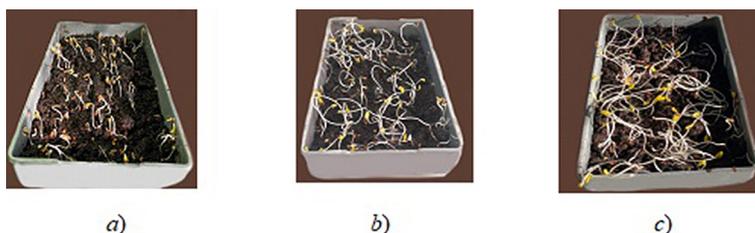


Figure 2. The view of test plants grown on soil sample without oil contamination (control) on the 3rd (a), 5th (b) and 7th (c) days of flax seed germination.



Figure 3. The view of test plants grown on artificially contaminated soil samples, in the amount of 100 APC on the 3rd (a), 5th (b) and 7th (c) day of germination of flax seeds

stimulated (hormesis, hypercompensating effect). On the fifth and seventh days of incubation, the growth of saliva was inhibited. It was found that on the third and fifth days of incubation of plants on the soil samples with oil content of 10 and 100 APC, the flax growth was inhibited, whereas on the seventh day of observation – it

was stimulated. At the oil product concentration of 1000 APC, the plant growth was inhibited at all stages of observation.

From the analysis of Figure 5 it is seen that from the third to the fifth day of incubation of plants on the soil samples with the oil content from 1 to 100 APC, the growth of the stem part of flax plants was restored, which may complicate the interpretation of the obtained on the fifth day of observation of soil biotesting data contaminated with petroleum products. Thus, it is very important during soil biotesting to take into account not only the dose dependence, but also time.

The next step was to determine the phytotoxic effect of exceeding the APC on the content of aviation fuel in the soil. The phytotoxic effect (FE, %) (Table 3) was determined as a percentage of the length of the root and aboveground part of the formula [Cherniak, 2018]:

Table 2. The length of test plants grown on artificially contaminated fuel soil on the 3–7th day of germination of flax seeds

№	Length of three-day seedlings, cm	Length of five daily seedlings, cm	The length of seven daily seedlings, cm
1	7.6	12.99	15.73
2	7.1	11.96	14.11
3	5.99	9.44	15.86
4	2.21	2.41	7.38
5	1.29	0.79	0

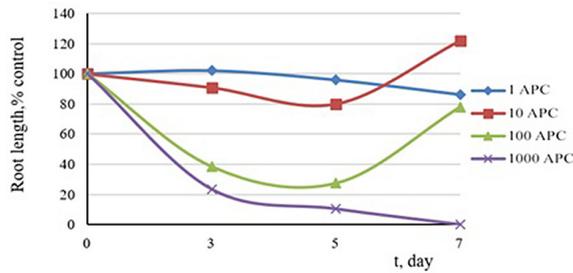


Figure 4. The dependence of the length of the root of flax seedlings on the time of germination

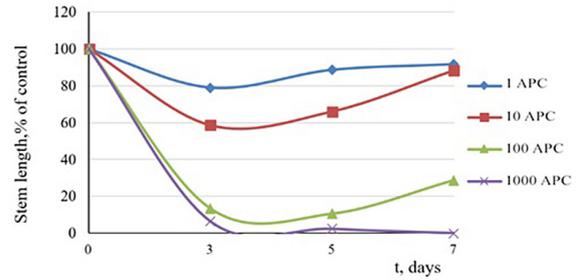


Figure 5. The dependence of the length of the stem of flax seedlings on the time of germination

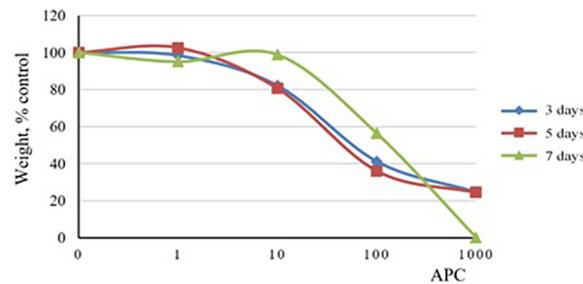


Figure 6. Comparative characteristics of the mass of raw material of 3, 5 and 7 daily flax seedlings

$$FE = \frac{(L_0 - L_x)}{L_0} * 100\%$$

where: L_0 – is the average length of the root or aboveground part of plants grown on soil samples from the control point;
 L_x – is the average length of the root or ground part of the plants grown on the soil from the studied areas.

In Figure 7–9, the dependences of the phytotoxicity index on the content of oil product in the soil are presented.

Substrate toxicity assessment was determined on a five-point scale [Vasilyev, 2012], according to which, a soil sample with a petroleum content at a concentration of 1 APC belongs to the average toxicity level, whereas a sample with a petroleum product concentration of 10 APC belongs to above average pollution, 100 APC and 1000 APC

of aviation fuel concentration in the studied soil samples – up to the maximum level of pollution.

Comparing the obtained results with the results of the study of soil samples [Yanovsky, 2016], selected at different distances from the tanks with fuel located at the airport, it can be concluded that at a distance of 2 m from the tank for the top layer of soil, its phytotoxicity to seedlings flax is weak, which indicates that, according to the obtained results, the level of APC for these soil samples is not exceeded. The level of toxicity for the growth of flax plant roots was medium, i.e. 1 APC of petroleum products.

The incubation of plants on the soil samples taken from the lower soil layer at a distance of 2 m from the fuel tank took place at a low level of toxicity for the growth of flax stalks, and for roots – above average, which exceeds the APC content of oil in the soil by about 10 times.

Table 3. Phytotoxicity index on the 3.5th day of flax seed germination

Phytotoxicity index					
3 days		5 days		7 days	
Root	Stem	Root	Stem	Root	Stem
-2.11	21.05	4.10	11.30	13.82	8.25
9.05	41.40	19.85	33.88	-22.11	11.57
61.47	86.67	72.46	89.40	21.97	71.23
76.63	93.68	89.67	97.68	100.00	100.00

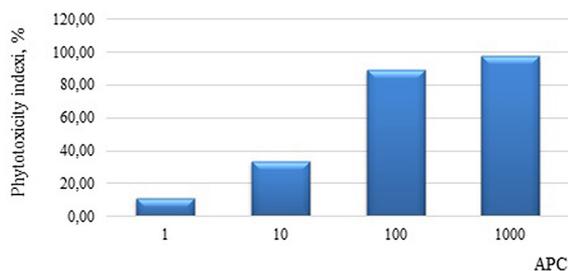


Figure 7. Comparative characteristics of the dependence of the phytotoxicity index of the root on the APC on the 3rd day of germination of flax seeds

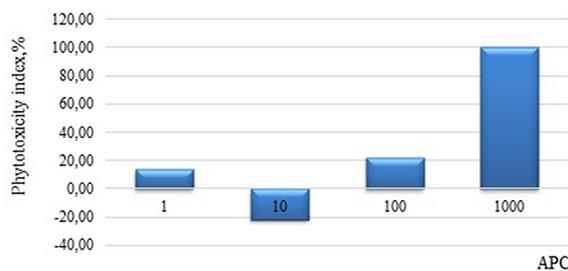


Figure 8. Comparative characteristics of the dependence of the phytotoxicity index of the stem on the APC on the 3rd day of germination of flax seeds

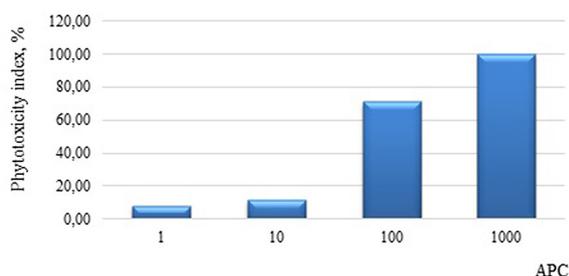


Figure 9. Comparative characteristics of the dependence of the root phytotoxicity index on the APC on the 5th day of flax seed germination

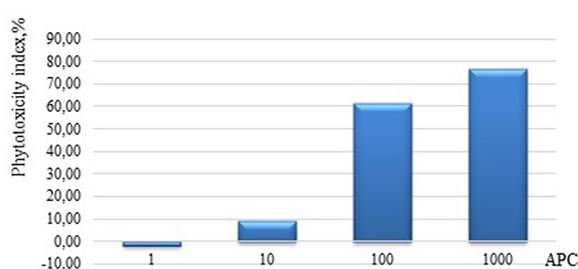


Figure 10. Comparative characteristics of the dependence of the phytotoxicity index of the stem on the APC on the 5th day of germination of flax seeds

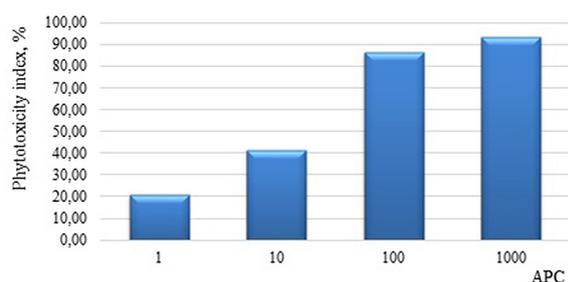


Figure 11. Comparative characteristics of the dependence of the phytotoxicity index of the root on the APC on the 7th day of germination of flax seeds

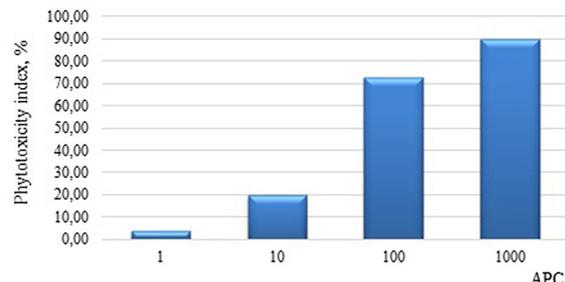


Figure 12. Comparative characteristics of the dependence of the phytotoxicity index of the stem on the APC on the 7th day of germination of flax seeds

CONCLUSIONS

The analysis of the results of experimental studies involving biotesting of soil artificially contaminated with aviation kerosene revealed the dependence of the plant growth parameters on the concentration of aviation kerosene in the soil, which indicates a sufficiently high sensitivity of flax as a test object to the pollutant. In order to obtain unambiguous conclusions about the effect of pollutants on test plants, it is necessary to take into account the dynamics of the values of their growth parameters.

The analysis of the obtained results regarding the phytotoxic effect of soil samples artificially contaminated with kerosene confirmed the

increase of the phytotoxic effect with the increase of the oil content in the soil sample.

A comparative analysis of the obtained results with the results of studies of phytotoxicity of soil samples taken at the airport, at different distances from the tank tanks, made it possible to establish the level of APC content of petroleum products at the airport. The level of toxicity of soil samples taken from the lower level is much higher.

Comparing the concentration dependences of the action of petroleum products on the growth rates of seedlings and their dependence on the distance to the source of contamination allows in the latter case to conduct a kind of “dosimetry” of exposure concentrations in the case when the petroleum product concentration was not determined.

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