Research of qualitative properties of soils during construction works

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Abstract. The development of humankind leads to an increase in the number and variety of sources of environmental pollution, to an increase in the volume of emissions of harmful substances. In urban conditions, environmental pollution occurs due to emissions of exhaust gases coming from various cars, leaks of fuels and lubricants coming from different equipment, etc. Analysis of the current state of urban areas shows the highest concentration of pollutants being present in soils. The article considers the problem of territories of construction sites contaminated with combustible substances coming from construction machinery, such as gasoline, kerosene and diesel fuel. These contaminants lead to the suppression and death of ornamental plants planted at the final stage of construction works. The authors describe in detail the methodology and results of laboratory studies of the process involving penetration of these contaminants into the soil. On the basis of the results obtained, recommendations are proposed for minimizing the negative impact of these factors on the soil and increasing the efficiency of work on the improvement of adjacent territories.

1. Introduction
Construction work has a negative impact on natural complexes. In the construction areas, one can observe high levels of air, water, soil pollution. This occurs at all stages of construction [1-3]: during design and survey work, during the construction of temporary access and adjacent roads, when arranging open pit mines for foundation, as well as directly in the process of construction of buildings and structures at the construction site. Each stage of construction is characterized by its own sources of negative impacts and characteristic pollutants. When performing any of the above works, the soils will be the components of the environment suffering the greatest from building mechanisms and materials, since they are the most inert environments with a low rate of self-cleaning process [4-6].

Under the influence of gravity, the upper layer of the soil is compacted, its porosity and moisture levels change, the soil may lose its ability to absorb and retain moisture, its water permeability decreases. Apart from changes in the physical properties of the soil, in the process of performing various works, soil contamination occurs due to bulk materials hitting the surface, as well as spills of fuel and liquid building materials, thereby causing changes in the chemical parameters of the upper soil layer [7-8]. Over time, contaminants that hit the surface penetrate into the soil assisted by rain and melt water. That is why it is not uncommon for the soil to be contaminated with heavy metals and various oil products [9-11]. With long periods of soil contamination and the achievement of high concentrations of oil products, irreversible changes occur in it, which further affect the biodiversity of the area and the vital activity of soil animals [12-13]. The thickness of the soil in which such changes take place depends on
the type of soil, particle-size distribution of the original soil, as well as the precipitation depth and the amount of oil products that have hit the soil.

Responses to pollution from vegetation and wildlife are mixed. Small amounts of these pollutants may not cause any adverse effects if spilled into the ground. However, with significant volumes of pollution in the course of first few days, we observe the death of most soil animals for which the light fractions of oil are considered the most toxic.

At the end of construction work, landscaping improvement is carried out on the adjacent territories, i.e. playgrounds, flower beds and recreation areas are arranged. The possibility of soil contamination with oil products must be taken into account when carrying out such work. Since the processes of soil restoration in contaminated areas are slow, the ingress of oil products into the soil leads to a change in the photosynthetic functions of higher plants in the adjacent territories and slows down the germination or survival of annual and perennial plants planted for improvement [14]. Even low concentrations of oil products in soils lead to oppression of plants. The ingress of 1.1 l/m² of oil can lead to complete death. It can take up to 20 years to restore the soil so highly contaminated.

Many scientists are studying the process of penetration of oil products into the ground and the degree of its influence on vegetation [15-19]. As a rule, these are analytical predictions of the process involving penetration of substances into the soil, the spread of contaminants into the soil, the analysis of the dynamic characteristics of such spreads, as well as the determination of the amount of pollutants at different depths. It is also noted [18-20] that the degree of influence of pollution on vegetation depends on the quantitative indicators of the pollutant amounts in the soil. The purpose of this work is to conduct field studies of the process of penetration of oil products into the soil on a physical model. During the experiments, only the seepage of pollutants into the soil by gravity is investigated, while the lateral spread of oil products is excluded.

2. Methods
The results of any study involving soils depend on correct sampling and pretreatment. Therefore, at the preparatory stage of the research, soil samples were taken on the territory of the city in order to determine the particle-size distribution and type of soil. The sampling sites were outlined on a coordinate grid listing their numbers and coordinates. The sampling points were located at equal distances from each other. The results of the study show that the particle-size distribution of the soil in the urban area is close to the particle-size composition of river sand. In accordance with the theory of similarity, sand can be used for further laboratory research.

For the experiments, the most common fluids used in the operation of construction machinery at the construction site were selected: gasoline, kerosene, diesel fuel. A plastic pipe with a height of about 25 cm - the depth of penetration for the bulk of the root system of annual ornamental plants [20-21] was taken as a container for the experiments.

![a) b)](image)

Figure 1. The process of penetration of contaminants into the soil (a – the first minutes of the experiment, b – the type of soil after 5 minutes).
The sequence of the experiments: The container was filled with sand. Continuous compaction was carried out during the filling. Then, using a measuring glass, the required volume of the test liquid was measured and poured onto the surface of the sand (figure 1). The volumes of 50, 100 and 150 ml took part in the experiment. The time of penetration of oil into the sand was recorded with a stopwatch. The depth of penetration was measured after 1, 3, 5, 10, 15, 30 minutes, then after 1, 2, 3, 6, 12, 18, 21 hours and one day after the moment of contamination.

3. Results and Discussion
Some research results are presented in the form of graphs reflecting the dependence of the penetration depth of the polluting liquid on the penetration time (figure 2-4).

Figure 2. Results of a series of experiments on the penetration of kerosene (100 ml volume). Vertical – penetration depth in cm, horizontal – observation time in minutes.

Figure 3. Results of a series of experiments on the penetration of gasoline (100 ml volume). Vertical – penetration depth in cm, horizontal – observation time in minutes.
The results of the studies have shown the unevenness with which the penetration of polluting liquids in the soil took place over time. The highest penetration rate is observed in the first hour after the ingress of contamination to the soil surface. With the smallest investigated volumes of contamination hitting the surface (50 ml), the soil becomes contaminated to the depth of 10 to 12 cm within an hour. If more liquid hits the soil (100 ml) the following is observed: diesel fuel penetrates 10-13 cm into the soil in an hour, kerosene penetrates 12-14 cm deep into the soil, and gasoline penetrates to a depth of 12-15 cm. The results of experiments with volumes of 150 ml showed that kerosene and gasoline reach a penetration depth of 21-23 cm after 30 minutes. Then there is a significant slowdown in speed penetration and the maximum penetration depth recorded in a day is 34-35 cm. It should be noted that the penetration of the liquid continued for several hours after all the liquid above the surface penetrated into the ground. Moreover, a larger amount of polluting liquid (up to 80%) is concentrated in the soil to a depth of 15-20 cm due to the liquid viscosity and the slowing penetration rate.

The graphs indicate that the higher the initial height of the liquid layer above the ground, the more intense the initial process of liquid penetration. Moreover, the dependence of the liquid viscosity and the intensity of penetration is observed. The viscosity of kerosene and diesel fuel is lower than that of gasoline, and the density is higher [22]; therefore, the graphs show that gasoline penetrates to greater depths and the process of gasoline penetration is more intensive.

**Figure 4.** Results of a series of experiments on the penetration of diesel fuel (100 ml volume). Vertical – penetration depth in cm, horizontal – observation time in minutes.

4. Conclusions
The conducted studies of the process involving the penetration of oil products into the soil showed that the highest rate of penetration occurs in the first hours of the ingress of pollution to the soil surface. During construction work, it is necessary to immediately eliminate the spill of oil products to minimize the depth of pollution. This practice is typical for leaks on oil pipelines. On the territory of construction sites, the ingress of oil products in large quantities is extremely rare, therefore, uncontrolled contamination of the soil of construction sites with small volumes of oil liquids occurs.

As field studies have shown, by the time the improvement work begins, the soil can be contaminated to a depth of 25 cm and below. Consequently, in the places where ornamental planting is planned, it is necessary to remove at least 15 cm of the contaminated soil in order to prevent the plants death.
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