Contamination of Soils and Sub-Soils at Construction Sites

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Abstract. Construction works, like any anthropogenic activity, have a negative impact on natural complexes. High levels of air, water and soil pollution are observed in areas of construction. This occurs at all construction stages: during the design and survey work, during the construction of roads and quarries, directly during the work on the construction site. Each stage of construction results in a new pollutant appearing each time. The greatest problem is the contamination of soils and sub-soils: soil dumps on construction sites, using bulk construction supplies, storing various supplies on the construction site, washing off bulk materials into the areas adjacent to the construction site, and the contamination of soil with fuel. The paper presents the results of the study describing the process of penetration of oily liquids, exemplified by kerosene, diesel fuel and gasoline. Studies were conducted in the laboratory. Sand is used as soil in accordance with the similarity criterion. Each type of fuel underwent series of tests with different volumes 50, 100 and 150 ml. The minimum number of tests in the series – 6. The minimum testing time for each series – 24 hours. The results of the study were analyzed and presented in the form of tables and graphs. The study revealed the following. Initially, the process of penetration is the same for all liquids tested. With the minimum tested volume, the average penetration depth for gasoline was 16.7 cm, for kerosene – 12 cm, and for diesel fuel – 21.5 cm. With the maximum tested volume, the average penetration depths were 21 cm, 21 cm and 21.5 cm, respectively. The studies also showed that, at the initial period, diesel fuel penetrates the sub-soil more slowly compared to all other tested liquids. This is due to a higher level of viscosity. The paper considers ways to reduce the impact of soil contamination on biota, as well as ways to eliminate this negative impact, leading to an increase in the efficiency of land improvement works, which take place after construction.

1. Introduction
Soils and sub-soils are the most important components of the natural environment. The condition of the soil layer largely determines the ecological balance of the ecosystem as a whole. During construction works, the soil on the construction site is destroyed. The arrangement of a construction site leads to the formation of local construction wastes, pollution and soil erosion processes, as well as changes in the landscape.

Various types of machinery are used at the construction sites. This machinery not only pollute the atmosphere at the construction sites and adjacent territories, but also have a negative impact on the soil surface layer [1-4].

Many scientists study the contamination of urban soils, in particular the penetration of petroleum products (which are one of the most dangerous types of contaminants) into soils and sub-soils [1-3]. At
high concentrations and long periods of exposure to soil, petroleum products cause irreversible changes: the soil loses the ability to absorb and retain moisture, the level of soil moisture and its permeability are reduced, etc. [5-10].

At construction sites, oil products enter the ground directly due to construction machinery, which causes a manifold increase in soil contamination in certain territories.

It should be noted that the soils with light grain texture and high effective porosity, are able to retain petroleum products in significant quantities. Since the natural decomposition of oil products is a long process, in order to minimize the consequences, it is necessary to conduct monitoring studies of the soil in order to determine the degree of contamination, to develop and carry out restoration activities after construction is completed.

Carrying out field studies of soil and sub-soil contamination at construction sites during the operation of machinery is complicated [11–14]. For that reason, laboratory tests were conducted to study the change in the intensity of the contamination process.

Penetration of contaminants into the soil is directly related to the size of the soil particles [15-17]. The granulometric composition of the soil of the Samara region is close to the granulometric composition of the river sand. In accordance with the theory of similarity, we can use sand in our laboratory research.

2. Materials and methods

Experimental studies on the process of petroleum products penetration into the soil were carried out on physical models. It is known that the use of hydraulic modeling is possible if hydrodynamic similarity is observed. Two streams are considered hydrodynamically similar if all the parameters characterizing their movement are mutually proportional at all similar points. Hydrodynamic similarity is ensured by observing geometric, kinematic and dynamic similarity.

Kinematic similarity takes place while observing the geometric similarity. At the same time, at similar points in hydraulic systems, the trajectory of movement of particles for fluids or streams is geometrically similar.

Ensuring complete concurrence of physical processes occurring in natural conditions is almost impossible to model. In this case, the simulation is carried out with the closest approximation to real environmental conditions.

![Figure 1. Tanks filled with sand](image-url)
During the field studies, the presence of several types of soils within urban territories was observed, such as sandy loam, clay loam and black earth. For this purpose, the tanks of the same diameter with a minimum height of 21 cm were prepared. The tanks were filled with homogeneous sand. To obtain sand homogeneity while filling the tanks, the sand was occasionally settled.

Next to each tank filled with sand (figure 1), a measuring ruler was attached, which allowed to record the current level of penetration of petroleum products.

The most common liquids used in the operation of construction machines at the construction site were taken for testing: gasoline, kerosene, diesel fuel. The liquids were taken in the amount of 50, 100 and 150 ml and, with the help of a measuring cup, evenly poured over the entire sand surface. A stopwatch was used to measure times in which the liquids penetrated the sand. The experiment lasted for 48 hours (figure 2).

![Figure 2. Penetration of liquid into the sand](image)

3. Results and discussions
The results of testing on penetration of liquids are presented in tables 1-3.

| Test No. | Penetration depth, cm After 1 min | After 2 min | After 5 min | After 10 min | After 15 min | After 30 min | After 24 hours |
|---------|----------------------------------|-------------|-------------|--------------|--------------|--------------|----------------|
| 1       | 7                                | 8           | 9.5         | 11.5         | 12           | 14           | 19             |
| 2       | 4                                | 6           | 9           | 12           | 13           | 14.5         | 18             |
| 3       | 5                                | 7           | 8           | 10           | 11           | 12           | 17             |
| 4       | 5                                | 7.5         | 9.5         | 11           | 12           | 13.5         | 19             |
| 5       | 4                                | 6           | 8.5         | 10.5         | 11           | 14           | 19             |
| 6       | 5                                | 7           | 8           | 10           | 11.5         | 13           | 18             |

| Test No. | Penetration depth, cm After 1 min | After 2 min | After 5 min | After 10 min | After 15 min | After 30 min | After 24 hours |
|---------|----------------------------------|-------------|-------------|--------------|--------------|--------------|----------------|
| 1       | 5                                | 6           | 7.5         | 9            | 10           | 12.5         | 20             |
| 2       | 6                                | 7           | 8           | 9            | 10           | 11           | 21             |
| 3       | 5.5                              | 6           | 8           | 10           | 10.5         | 11           | 20.5           |
| 4       | 6                                | 7.5         | 9           | 10.5         | 12           | 14           | 19             |
| 5       | 8                                | 9           | 10           | 12           | 12.5         | 15           | 19             |
| 6       | 7                                | 8.5         | 9.5         | 11           | 13           | 15           | 18             |
Table 3. Results of tests for diesel fuel penetration (150 ml volume)

| Test No. | Penetration depth, cm |
|----------|-----------------------|
|          | After 1 min | After 2 min | After 5 min | After 10 min | After 15 min | After 30 min | After 24 hours |
| 1        | 4           | 4.5         | 5.5         | 10           | 12.5         | 15.5         | 21.5          |
| 2        | 4           | 4.5         | 7.5         | 9.5          | 11           | 13.5         | 21.5          |
| 3        | 4.3         | 5           | 6.5         | 10           | 12           | 15.5         | 21.5          |
| 4        | 3           | 4.5         | 7           | 10.5         | 11.5         | 15.5         | 21.5          |
| 5        | 3.5         | 4           | 7           | 10           | 12.5         | 16           | 21.5          |
| 6        | 3.5         | 5           | 8           | 10.5         | 12.5         | 15           | 21.5          |

Based on the results obtained, it is possible to build graphs depicting the process of penetration of each of the tested liquids into the sand.

**Figure 3** presents the results of tests of the penetration of gasoline into the sand. The horizontal axis describes the time of measurement (after 1 minute, 2 minutes, 5 minutes, 10 minutes, 30 minutes and 24 hours or 1440 minutes). The vertical axis – the depth of penetration at the time of measurement (in cm).

![Figure 3](image)

**Figure 3.** Graphs showing the dependence of depth of penetration for different volumes of gasoline versus time.

The first series of tests were performed with a 50 ml volume of gasoline (tests numbered 1, 2, 3, 4, 5, 6), the second series – with 100 ml of gasoline (tests numbered 1-1, 1-2, 1-3, 1-4, 1-5, 1-6) and the third series of experiments – with 150 ml of gasoline (tests numbered 2-1, 2-2, 2-3, 2-4, 2-5, 2-6). Similar graphs were obtained for other liquids tested.

From the graphs showing the measurements of the penetration of kerosene (volume 50 ml) into the sand, you can see that within the first minute after the spill all tests show the penetration depth of 5 cm (the same for all tests). The maximum penetration depth with the minimum liquid volume studied was 13 cm.

With an initial liquid volume of 150 ml, kerosene penetrates to a depth of 8–10 cm in the first minutes. Further, rapid penetration is observed and a maximum value of 21 cm is reached after 10 minutes. Then the process slows down.
Gasoline (with a volume of 50 ml) penetrates faster than kerosene in the first 10 minutes, further on, the liquid penetration proceeds evenly, without abrupt transitions, approximately 2-3 cm for each subsequent period of time between measurements. The maximum value of gasoline absorption (with a volume of 50 ml) equals to 18 cm per day, the average penetration depth under these conditions is equal to 16.7 cm. Moreover, as the initial volume of the liquid increases, the average penetration depth in the first minute increases up to 6.25 cm.

Initially, diesel fuel penetrates the sub-soil more slowly compared to all other tested liquids. In the first minutes, diesel fuel penetrated to a depth of 3.5-4.5 cm for all types of volumes. Further, slow penetration to a depth of 10 cm in 10 min is observed, and the maximum penetration depth of 21 cm is reached within 24 hours.

Based on the results of all test series, the average measurements were determined (figure 4).

![Figure 4. Graphs of the average values of liquid penetration](image)

The graphs show that the processes of penetration of kerosene and gasoline are similar. This can be explained by the same fluid density for both liquids. In contrast, diesel fuel penetrates more slowly, and absorbs evenly. Therefore, in order to achieve minimum soil contamination on the construction sites, it is necessary to timely remove soils contaminated with fuel fluids.

4. Conclusions
Soils of the construction sites (contaminated with oily products) facilitate degradation processes in soils and lead to the need for additional works on the landscaping of the territory. Planned measures aimed at the improvement of sites after the completion of construction work most often consist in territory planning and the arrangement of sidewalks and inland roads, parking spaces, and playgrounds. At the same time, soils of the construction sites (contaminated with oily products) facilitate degradation processes in soils and lead to the need for additional works on the landscaping of the territory. Planned measures aimed at the improvement of sites after the completion of construction work most often consist in territory planning and the arrangement of sidewalks and inland roads, parking spaces, and playgrounds.

At the same time, the removal of the top layer of soil is not always sufficient, since the thickness of the contaminated soil is already up to 20 cm or more within 24 hours after the spill.

Conclusions: On the territory of construction sites, soil is contaminated with various substances, including petroleum-containing contaminants.
The depth of penetration of petroleum substances depends on the time since the moment of soil contamination: a longer period of contamination corresponds to a greater depth of penetration of contaminant into the soil. The greatest depth of contamination is reached after 24 hours from the moment of the spill. Diesel fuel, unlike gasoline or kerosene, is characterized by a slower, longer process of penetration into the soil. With numerous and repeated contamination, oily contaminants accumulate, which facilitates the soil degradation processes, suppressing the development of vegetation.

References
[1] S. B. Scherbitsky, The Decrease in the Level of Environmental Pollution during the Construction Works on Urban Territory: Herald of SSAU. Urban planning and architecture, No. 2 (15), pp. 77-85, 2014
[2] V. N. Azarov, M. V. Trokhimchuk, A. K. Trokhimchuk, Experimental Study of Dust Dispersion In the Areas of Construction Dumps: News of higher educational institutions. Geology and exploration, No. 1, pp. 5, 2016
[3] E. O. Kozhevnikova, The Problem of Dust Contamination in Urban Areas While Performing Earth Works and Solutions: Alley of science, vol.1, No. 14, pp.676-688, 2017
[4] S. K. Nikolaev, M. A. Viktorova, D. Yu. Trushin, Experience in Assessing Contamination of Back-filled ground of Urban Areas According to the Environmental-Engineering Surveys: Geocology. Engineering Geology, Hydrogeology, Geocryology., No.4, pp. 328-336, 2006
[5] M. V. Trokhimchuk, A. K. Trokhimchuk, About Air Pollution of Urban Areas While Performing Ground Works: International scientific journal Alternative energy and ecology, No. 17-18, pp. 133-137, 2015
[6] A. N. Tetior, Restoration of Architectural Ecology: Sciences of Europe, No. 19 (9), pp. 22-32, 2017
[7] M. A. Vodianova, I. A. Kryatov, L. G. Donellan, I. S. Evseeva, D. I. Ushakov, A. V. Sbitnev, Hygiene and Sanitation, Vol. 95, No. 10, pp. 913-916, 2016
[8] V. I. Smetanin, E. V. Sekulow, Geoeconomic Assessment of the Impact of Construction on the Environment: Scientific life, No. 8, pp. 22-33, 2017
[9] Y. V. Shuvalov, E. A. Sinkova, D. N. Kuzmin, The Cleaning of Soils from Pollution by Oil and Petroleum Products: Mining information and analytical Bulletin, No. 12, pp. 107-117, 2004
[10] N. S. Gorobtsova, O. G. Labska, Comparative Analysis of Substances for Treatment of Soils from Oil Sludge: Successes of modern science, No. 1, pp. 17-20, 2018.
[11] A. P. Khaustov, M. M. Redina, Transformation of Oil Contaminants of Geological Environment under the Influence of Living Matter: Oil. Gas. Innovations, No. 10 (177), pp. 25-33, 2013
[12] A. V. Sadchikov, M. S. Chernykh, Neftegastruba and Bioremediation: Modern problems of science and education, No. 5. pp. 309, 2016
[13] R. F. Sagitov, S. V. Shabanova, S. P. Vasilevskaya, E. V. Voloshin, I. D. Alymov, G. E. Imangaliyeva, O. Sh. Tulegenova, Classification of Methods of Localization and Elimination of Contamination of Soil by Oil and Petroleum products: Science and modernity, No. 1 (7), pp. 202-207,2016
[14] Gavrilin, I. I., Shigapov, A. M. Assessment of the Impact of Oil and Petroleum Products on the Status of Vegetation Indicators in Phytotoxicity of Soils // Systems. Methods. Technologies. 2015. No. 3 (27). Pp. 144-148.
[15] T. N. Morozova, E. S. Belik, L. V. Rudakova, The Use of the Bacterial Agent for Remediation of Industrially Contaminated Soils: Bulletin of Perm national research Polytechnic University. Applied ecology. Urbanis, No. 3 (19), pp. 69-81, 2015
[16] M. I. Balzannikov, Yu. M. Galitskova, N. In. Akhrameeva, S. V. Sholomov, Assessment of Pollution in the Production of Building Blocks Made of Aerated Concrete, Industrial and civil engineering, No. 6, pp. 62-66, 2014
[17] Yu. M. Galitskova, A. I. Murzayeva, Urban soil contamination: Procedia Engineering, vol. 153, pp. 162-166, 2016