Geoecological evaluation of environmental damage to the results of long-term dynamics of benzopyrene and petroleum within landfill sludge

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Abstract. The article deals with the problems of environmental pollution with benzapyrene and petroleum products contained in sewage sludge. The dynamics of changes in the concentrations of benzapyrene and petroleum products in the soils of the object of accumulated environmental damage (landfill sludge) is analysed, the main criteria for the identification of environmental damage for these pollutants are determined.

1. Introduction
Accumulated environmental damage (AED) objects - contaminated areas and water areas where economic and other activities were carried out, including the disposal of hazardous waste [1, 2, 3], are the major source of surface-water contamination.

The emergence of AED objects in the wastewater treatment system has led to significant environmental risks of environmental pollution [4, 5]. It is linked with such hazardous pollutants as benzopyrene and petroleum products.

Benzopyrene and petroleum products usually enter ecosystems from areas affected by industrial zones, as well as from major highways with heavy traffic [6].

Both lipophilicity of benzopyrene and petroleum products and their ability to settle on solid particles are conductive to their long-term presence in the environment and cause their atmospheric transport with dust particles, over-the-surface flow and atmospheric precipitation.

In this regard, the purpose of the research is to assess the environmental risk of petroleum products and benzapyrene entering the soil during long-term disposal of sewage sludge at landfills (AED objects). Subject of the study is the Saint Petersburg sewage sludge landfill located in the hydrographic water basin zone of Neva Bay and eastern part of the Gulf of Finland.

2. Materials and Methods
The research included field work on sampling according to GOST 17.4.4.02 “Soils. Methods for collection and preparation of samples for chemical, bacteriological, helminthological analysis”.
Sampling (of soddy podzolic soils) was carried out from the soil surface to a depth of 5-20 cm by the envelope method. The method of infrared spectrometry was used for the determination of petroleum products according to the RF.1.31.2005.01715 method (error characteristics $\delta = 30\%$). The studying of benzapyrene concentrations was carried out according to the RF.1.31.2004.01279 method. The SPSS Statistics 22 software package was used for statistical processing of the results obtained.

3. Results
Over the course of the study of soil contamination under the chosen points of an AED object, in all cases the benzapyrene concentration range varied from 2 to 780 $\mu$g/kg (MPC = maximum permissible concentrations - 0.2 $\mu$g/kg). This indicates an insignificant effect of benzpyrene on the environment (as a hazardous component).

The variable array of petroleum product concentrations is in the range from 50 to 4600 mg/kg, which indicates a significant non-uniformity of contamination. This is probably caused by season-related contamination (oil products proportion in the sewage sludge composition is much higher in the summer period) or the longer operation of vehicles at a certain part of the landfill in the sampling zone. At the same time, the data obtained indicate a significant contamination of the areas being studied.

4. Discussion
Wastewater treatment is accompanied by the fat fraction separation (petroleum products, natural and technical fats, etc.). A mixture of the formed sewerage system wastes is usually utilized on silt detention ponds (with an open and concreted base) and on landfills.

The inhibitory effect of petroleum products and benzapyrene on the activity of soil enzymes is manifested in a change in the composition and organization of the amylolytic microbial community of the soil, which corresponds to the reaction zones of the soil microbial system to contamination [7]:

- homeostasis (C oil 0 - 0.7 ml/kg of soil): all indicators are stable and almost indistinguishable from the target values.
- stress (C oil 0.7 - 50 ml/kg of soil): the organization of the amylolytic community changes significantly, the first disturbances occur in the microbial community typical of this soil.
- resistance (C oil 50-300 ml/kg of soil): sharp decline in species diversity and change in the composition of the community, a complete change in the dominant forms in the microbial community.
- regression (above 300 ml/kg of soil): complete inhibition of the growth and development of microorganisms in contaminated soil.

There are a number of studies [8] devoted to the decomposition of petroleum by bacterial microflora in the surface layers of an impounded surface water and soil. These processes are partly specific to the AED objects being studied.

A distinctive feature of an AED object being studied is the storage (burting) of waste batches, the process by which cascades of toxic waste masses are formed with the creation of an anoxide zone. It redounded to both physical and chemical nature of petroleum products, the supply of which fills the pore space of the soil displacing the soil air, and thereby disrupting the natural processes of aeration [9] and microbial self-cleaning of the soil [10].

All this leads to an increase in the time cycle of sewerage system wastes bio-conversion and, in particular, of the microbiological destruction of both benzopyrene and petroleum products.

The results of the long-term dynamics of changes in the concentrations of both petroleum products and benzapyrene in the AED object soil show that their highest concentrations are in the area of the most frequently used landfill sediment collectors (points 1, 2, 3, 4 in figure 1). The rest sections (points 5, 6, 8, 9) have different degree of contamination with a small increase of the concentrations at the point 7.
Figure 1. Benzapyrene and petroleum concentrations in soil.

Legend: \(\text{benzapyrene (µg/kg), petroleum products (mg/kg)}\)

The benzapyrene concentrations were within the MPC standard limits in the course of the entire study period, which makes it possible to detect the absence of negative impact from this pollutant on the soil. Based on the evaluation criteria obtained as a result of various studies, it is possible to assess the degree of soil contamination on the AED object territory with oil products as highly polluted (table 1) [11].

| Contamination level category | Petroleum products content, mg/kg |
|-----------------------------|----------------------------------|
| Uncontaminated              | < 5                              |
| Slightly contaminated       | 5–100                            |
| Medium contaminated         | 101 - 500                        |
| Heavily contaminated        | >500                             |

However, the absence of the MPC standard on oil products for soils makes the problem of both identifying and systematizing the AED to be more complicated.

In this regard, the proposed options for geo-environmental assessment of the negative impact on the environment of petroleum products (table 1) found on the AED objects territory are specific for
each territorial entity and are due not only to industrial (anthropogenic) load, but also to physical and geographical indicators.

5. Conclusion
For Russia, challenges of assessing the level of soil contamination with petroleum products is a debatable matter up to the present moment, so the evaluation criteria are not standardized and have different values among the researches [4, 7], which largely depends on the local factors related to the functional feature of the object under observation.

However, it should be noted that the long-continued inflow of both petroleum products and benzopyrene into the soil when disposing of sewage sludge at AED objects located in the hydrographic water basin area can be a source of negative impact on surface watercourses and water-storage basins, which exacerbates the challenge of assessing and eliminating environmental damage from this categories of objects [12, 13].

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