Assessment of the ecological state of soils in roadside territories using chemical and biological indication

V O Iurchenko¹,³, I B Ugnenko², O G Melnikova¹, O V Rachkovskiy¹ and P S Ivanin¹

¹Department of Life Safety and Environmental Engineering, Kharkiv National University of Civil Engineering and Architecture, Sumskaya str. 40, 61002, Kharkiv, Ukraine
²Department of Surveying and Designing of Communication, Surveying and Land Management, Ukrainian State University of Railway Transport, Feierbakh Square 7, 61050, Kharkiv, Ukraine

Abstract. Chemical and bioindication studies of soils in the roadside areas of railways and highways have been carried out. The studies have shown that on the territories directly adjacent to the transport routes, the concentrations of the petroleum products in soils are 1.6-32.4 times exceeding the APC (approximate permissible concentration). The most substantive exceedances of the APC are recorded in the highways roadside spaces. We have investigated the dependence of the petroleum products concentration in the soils and their bioindication indices on the distance to transport routes. It has been established that the pollution of roadside soil by petroleum products decreases sharply at a distance of 10-15 m from transport routes. And bioindicators show different dynamics with increasing distance from the source of pollution (and, consequently, decrease in concentration of petroleum products in soils): the intensity of respiration of soils increases, and catalase activity decreases, which reflects its characteristic as an enzyme of stress. According to bioindication data, it has been shown, that the soils of the roadside space (especially, as for railways) retain high restorative potential.

1. Introduction
Land management should provide ecologically, safe, and cost-effective land use. The former is an effective mechanism in the organization of land as a means of production and greatly improves the regulation of social relations in terms of the possession, use, and disposal of land [1].

One of the sharpest problems of rational and environmentally sound land use is the contamination of soils by solid, liquid, and gaseous wastes of technogenic origin. The transport system is one of the key important developmental and functional conditions of modern industrial society; it creates an extremely intense technogenic impact on the soil environment as a result of intensive emission of pollutions [2]. It is possible to assess the ecological state of the soil environment, which undertakes the technogenic influence, using both chemical and biological parameters [3, 4]. Moreover, if the chemical parameters indicate the level of contamination of the substrate, the danger of which can be estimated by comparing this parameter to the normative permissible values (MPC, APC), then the biological parameters allow to
judge about the changes in the state of the biota in specific pollution conditions and the degree of environmental hazard for all living organisms, including human beings.

If the ratio of exceeding the maximum permissible concentration (MPC) is to be assessed, then pollution by the petroleum products (PP) creates the greatest environmental hazard for roadside soils [5]. However, as noted, for the objective assessment of the ecological state of these grounds and their restorative potential, a chemical indication alone is not sufficient. It is necessary to evaluate and forecast the state of soil biota using biological indication [3].

The most sensitive and specific are the bioindication parameters of the biochemical and physiological level, which, moreover, allow the detection of violations at the initial stage of the process. Soil respiration is used as one of the most general indicators of biotic soil activity: carbon dioxide emission and oxygen absorption.

The total intensity of the soil respiration (RI) is conditioned by its general biological activity. Studies by various authors have proven that the activity of soil enzymes can serve as an additional diagnostic parameter of soil fertility and its changes as a result of anthropogenic influence [6, 7, 8]. First of all, when monitoring and diagnosing the soil conditions, biochemical parameters should be defined as more sensitive and less variable, less labor-intensive, and less expensive ones. Among enzymes, the classes of oxidoreductases and hydrolases have the greatest bioindication value in terms of soil biodynamics. And among the oxidoreductases, present in the soil, one of the most common groups are the catalases, the enzymes that catalyze the detoxification of peroxide, which is formed in the metabolism of soil microflora.

2. Aim of the study
The purpose of the study is a complex experimental assessment of the soil pollution level and its ecological consequences using chemical and biological indicators in the roadside areas of various transport routes.

3. Objects and research methods
The objects of the experimental study were soils and snow from the territories adjacent to the railways and highways. Soil samples for the analysis were selected by the «envelope» method according to [9] at six sites located in the Kharkiv oblast, Ukraine. The researchers used the ability of the PP emissions from the transport routes to deposit in snow cover. The snow samples were taken at a certain area from the entire depth of the snow cover, and meltwater has been analyzed.

The PP flow that was deposited by snow cover was calculated by the formula:

$$P = \frac{C \cdot V}{S \cdot t},$$

where $P$ – the PP flow, mg (m$^2$·day)$^{-1}$; $C$ – the concentration of PP in meltwater, mg / dm$^3$; $V$ – the volume of meltwater, dm$^3$; $S$ – the area where snow was selected for the study, m$^2$; $t$ – the snow exposure time, day.

The control sample was taken at a distance of ~ 200 m from the P-46 highway. The concentration of the PP in soil [10] and in the aquatic environment [11] (thawing snow) was determined gravimetrically. Physiological and biochemical characteristics of soils, respiration intensity (RI) and catalase activity (CA) were controlled according to the methods expounded in the specialized literature [12].

4. Results and discussion
The results of the chemical study of soils located in direct vicinity to the transport routes (5-7 m from the railway track embankment and the boundary line of the highways) are presented in table 1. As we can see,
in the investigated soils adjacent to the transport routes, the PP concentration increased following increasing traffic intensity of the respective vehicles. In general, the PP concentration in the investigated soils (except the roadside space of the railway in the Podvirky village) was 1.6 - 32.4 times higher than the APC (200 mg/kg). Soils of highways roadside territories are characterized by much higher PP concentrations than soils in areas adjacent to railways. This situation is probably because PP from roads is getting to the adjacent territories via two ways: by air (exhaust gases) and by water (rainoff from the surface of the road surface - surface wastewater). In the meantime, the PP from the railways is coming only via surface wastewater. This fact is conditioning the differences in the distribution of PP in the roadside areas at a distance from the road (figure 1, 2).

**Table 1.** The PP concentration in soils on the roadside territories adjacent to the transport routes.

| Roadside Area            | Traffic intensity, transport number per day | PP concentration, mg/kg |
|--------------------------|---------------------------------------------|--------------------------|
| Railroad (the city of Merefa) | 24                                          | 321                      |
| Railroad (Artemivka village) | 126                                         | 600                      |
| Railroad (Podvirky village) | 17                                          | 200                      |
| Highway M-03              | 25248                                       | 3280                     |
| Highway P-46              | 19200                                       | 1095                     |
| Control                   | 0                                           | 50                       |

![Figure 1. The concentration of the petroleum products in soils at different distances from the railway found in the Podvirky village.](image1)

![Figure 2. The concentration of the petroleum products in soils at different distances nearby the R-46 highway.](image2)

As we can see, for 10 m from the railway the PP concentration decreases three times, and for 10 m from the highway – only 2.2 times. In both cases, at a distance of more than 10 m from the transport route, the PP concentration in the surface layer of soil stabilizes itself, and in the roadside space of the investigated railway, it reaches the level of environmentally safe values. The sharp decrease in the concentration of PP in the soils of the roadside space, which occurs at a distance of 10-15 m from the conveyor belt, is probably due to reaching the limit of rainoff spreading. As an environment, depositing PP, which are coming from transport routes, the researchers used snow cover formed over some time over a certain area. Snow is an effective sorbent accumulator of various substances that are carried by the wind
or fall together with precipitation. As can be seen from the data in table 2, the flow of PP to the territory adjacent to the transport routes, significantly exceeded the flow of PP in the control area (2.5 mg/dm³):

| Roadside area       | Distance from the transport routes, m | PP flow, mg(m²·day)⁻¹ |
|---------------------|---------------------------------------|-----------------------|
| Р-46 Highway (windward side) | 5                                      | 264.7                 |
| Р-46 Highway (lee side)   | 20                                     | 41.7                  |
| P-46 Highway           | 1                                      | 114.8                 |
| (lee side)            | 5                                      | 40.0                  |
| Control               | 200                                    | 2.5                   |

Bioindication parameters of soil state on roadside territories responded differently to soil contamination by PP in table 3. The RI (for each of the kinds of transportation ways) decreased steadily with increasing PP concentration, and the CA mainly increased. Probably, this dependence is caused by the fact that the catalase is a stress enzyme and it reacts with a significant increase in its activity on the increasing PP concentration, which is noted by other authors [6, 7]. In general, at a distance of 20 m from the investigated railway, the RI has practically reached an ecologically safe level.

| Roadside area       | Distance from the transport routes, m | CA, cm³ KMnO₄ (g·h⁻¹) | RI, mg CO₂ (g·h⁻¹)⁻¹ |
|---------------------|---------------------------------------|------------------------|----------------------|
| Railroad            | 5                                      | 3.4                    | 1.21                 |
| (Podvirky village)  | 20                                     | 3.0                    | 1.90                 |
| P-46 Highway        | 5                                      | 4.8                    | 0.80                 |
| Control             | 200                                    | 3.6                    | 2.0                  |

5. Conclusions
The studies have shown that soils in the territories adjacent to the transport routes are contaminated with PP at concentrations exceeding 1.6-32.4 times the APC. Moreover, the PP concentrations in the roadside areas of the highways significantly exceed this index in comparison to the roadside space of the railways. Soil contamination by the PP sharply decreases at a distance of 10-15 m from the transport routes.

According to bioindication data, the soils in the roadside area of the studied railways practically restore their physiological activity at a distance of 20 m from the transport routes, and the soils of the roadside space of the roads significantly improve it.

References
[1] Kustovska O V, Kutsenko Yu A 2014 Economics and Ecology of Land Use 3 – 4 107
[2] Kuric I Mateichyk V, Smieszek M, Tsiuman M, Goridko N and Gritsuk I 2018 The peculiarities of monitoring road vehicle performance and environmental impact MATEC Web of Conferences ITEP’18 244 03003 https://doi.org/10.1051/matecconf/201824403003
[3] Pshenin V N 2008 Proceedings of the IV International Scientific and Practical Conference (St.
[4] Strik M, Telesinski A 2017 *Environment Protection Engineering* **43** (1) 151 DOI: 10.5277/epe170112

[5] Mykhailova L, Fischer T and Iurchenko V 2018 Microbial Activity and Decomposition of Soil Organic Matter in Roadside Soils Contaminated With Petroleum Hydrocarbons *Clean - Soil, Air, Water* **46** 1800132 DOI: 10.1002/clen.201800132

[6] Achuba F I and Okoh P N 2014 *Open J. of Soil Science* **4** 399

[7] Rusin M, Gospodarek J, Barczyk G, Nadgorska-Socha A 2018 Antioxidant responses of *Triticum aestivum* plants to petroleum-derived substances *Ecotoxicology* [https://doi.org/10.1007/s10646-018-1988-3](https://doi.org/10.1007/s10646-018-1988-3)

[8] Kumari1 B, Singh1 S N, Singh D P 2016 *Int. J. Environ. Sci. Technol* **13** 1029 DOI 10.1007/s13762-016-0934-2

[9] Soil quality. Sampling. Part 2 2006 *Guidelines for Sampling Methods* (ISO 10381-2: 2002, IDT): DSTU ISO 10381-2: 2004 (Kyiv State Consumer Standard of Ukraine)

[10] Measurement Methods 2011 *Soils. Gravimetric method for performing measurements of mass fraction of petroleum products (non-polar hydrocarbons): MVB № 081 / 12-0725-10* (Kyiv Ministry of Ecology and Natural Resources of Ukraine)

[11] Lurye Yu Yu 1984 *Analytical chemistry of industrial effluents* (Moscow: Chemistry)

[12] Ezirim C Y, Chikezie P C, Iheanacho K M Nwachukwu N R 2017 Comparative Activities of Soil Enzymes from Polluted Sites in Egbema, Imo State, Nigeria *J Pollut Eff Cont* **5** 185. doi:10.4172/2375-4397.1000185