1. Introduction

Ecosystems adjoining the highway are an immediate vehicle pollution acceptor. These ecosystems can have different characteristics (forest, meadow, agro ecosystems), but what unites them all is that the prevailing impact on them is exerted by emissions from motor vehicles. The continuous growth of vehicle fleet and traffic flow intensity lead to load increment in the above-mentioned ecosystems. Therefore, to research them is an urgent task.

Plants give a well-defined response to abiotic changes, thus, performing an indicative role. The chemical composition of plants reflects exactly that elemental composition of the environment in which their development occurs. Plant bioindication of the environmental condition is believed to be one of the most accessible techniques for estimating anthropogenic load [1]. Besides, the undeniable advantage of bioindicative assessment is that we observe the «live» response of a particular biocenose to changes in the environment.

2. The object of research and its technological audit

Ecosystems directly adjoining interstate, state and regional highways (Fig. 1) were selected as an object of research. They are:

1. H12 (Sumy – Poltava) – close to the town of Okhtyrka.
2. H07 (Kyiv – Sumy – Yunakivka) – close to the town of Romny.
3. P44 (Hlukhiv – Sumy) – close to the town of Bilaopolya.
4. M02 (Kipti – Hlukhiv – Bachivsk) – close to the town of Baturin.
5. M03 (Kyiv – Kharkiv – checkpoint Dovzhansky) – close to the town of Pyriatyn.

Fig. 1. Highway sections under investigation
Traffic flow intensity in the investigated areas was determined by means of calculation in accordance with the procedure provided in [2]. The results are shown in Fig. 2.

Fig. 2. Traffic intensity (vehicle density) in the investigated highway sections

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One of the most urgent problems is the detection of trends of the impact of the vehicles movement characteristics on roadside ecosystems. After all, along with the increasing intensity of movement in the selected areas, other factors also have negative influence, the roadway condition in particular. In places with existing rocks, irregularities, the speed of the car goes down to the ranges in which the amount of pollutant emissions in the atmosphere is significantly increased. This gives grounds for expecting an increase in the load on the roadside ecosystem, which predetermines this research.

Assessment of roadside ecosystems is a perspective and difficult task. Roadside ecosystems are a direct acceptor of transport pollution and are subject to simultaneous exposure to both harmful atmospheric impurities and washing of contaminants from the highway.

3. The aim and tasks of the research

The aim of the research is a bioindicative assessment of the condition of roadside ecosystems with different bioindicators.

To achieve this aim, the following tasks are defined:

1. To estimate the level of air pollution along highways according to the state of roadside ecosystems.
2. To estimate the level of soil contamination along highways.

4. Research of existing solutions of the problem

The bioindicative assessment of the condition of roadside ecosystems should be based on an integrated approach. Plants are clearly responsive to environmental changes and can play an indicative role as noted in the work [3, 4]. At the same time in the works [5–7] is recommended to use not one but several phytointdication methods to make environmental assessments more reliable, in particular to supplement it with phytotesting of soils. Soils state can be considered as an integral indicator of the multi-year pollution process. After all, substances that enter into the atmosphere with the exhaust gases, deposited in the soil and accumulate there as the authors [8, 9] point out. Phytotesting is based on the sensitivity of plants to exogenous chemical aggression, which affects the growth and morphological characteristics [10]. This allows the test body to respond to the relevant reaction of the entire set of toxic agents. The laboratory methods of phytotesting are especially important in environmental control as the most rapid and economical [5]. Various types of plants are used for phytotesting (salad, mustard, cereals, etc.).

The most suitable atmospheric pollution bioindicators (especially SO2) are lichens [11, 12]. The sensitivity of lichens to environmental pollution is conditioned by their physiology and symbiotic nature. The lasting action of low-concentrated pollutants causes such damages to lichens which do not disappear until the death of their thalli as notices in [13].

Of all the ecological groups of lichens, the most sensitive are lichen-epiphytes which are sensitive to changes in the air of some chemical elements and compounds included into motor vehicle emissions (sulfur dioxide, nitrogen oxides, heavy metals) [12]. The monitoring takes into account the frequency of finding lichens in the study area, as well as their projective cover that makes it possible to draw a conclusion about air quality [14]. In [15] is proposed to determine the degree of air pollution according to presence or absence of certain species of lichens.

Thus, in order to assess the condition of roadside ecosystems, methods of lichen indication and phytotesting have been selected.

5. Methods of research

The study of plant groups was carried out in the areas along the designated highways. It was taken into account that the plants suitable to be indicators had to meet the following requirements:

- wide ecological amplitude;
- wide distribution area;
- low spontaneous frequency of the accountable sign.

The selected experimental procedure is the universal non-specific indicator of the environmental condition, therefore, it does not require additional chemical and analytical work to confirm its aptitude.

The bioindicative studies were carried out by optical methods. Interpretation and experimental data processing were performed with the help of software products ABBY Finereader 9.0 and Adobe Photoshop 8.0.

In order to check the obtained observation data, index of atmospheric purity (I.A.P.) was calculated by D. DeSloover and F. LeBlanc’s methodology [16]. The evaluation of a computation result is carried out in compliance with the following logic: the higher the result, the less ecologically favourable the area is. This coefficient is calculated in total for all the sections and reflects the average pollution level throughout the terrain. For this purpose, used the formula:

\[
I.A.P. = \frac{1}{10} \sum_{i=1}^{n} Q_i \cdot F_i
\]

where \(n\) – the number of lichen species in the area under investigation; \(Q_i\) – an ecological indicator of the species \(i\) (an average number of species growing together with the species \(i\) in the investigated area); \(F_i\) – frequency of oc-
currence/species covering i in accordance with the given scale [15].

The product of $Q_i F_i$ is divided by 10 to get a more graphic figure.

Phytotesting is employed as a method for soil quality assessment. Experimental technique provides for soil sampling from the investigated sections with the further growing test-object on them. Control is taken over seed germination energy, germinant root length and germinant height. Depending on germination energy of seeds on the test substrates, they are assigned one of the four levels of pollution [17].

1. No pollution. Seed germination reaches 90–100 %. Seedlings are unanimous, germinants are strong, regular.
2. Weak pollution. Germination is 60–90 %. Sprouts are of almost normal length, strong, regular.
3. Medium pollution. Germination is 20–60 %. Sprouts are much shorter and thinner. Some of them are malformed.
4. Severe pollution. Seed germination is poor (less than 20 %), germinants are small and malformed.

To assess soil toxicity, we determine a phytotoxic effect (inhibitory effect) which depends on the average root length in the experiment and the average root length in the control. It is calculated by the formula [17]:

$$ FE = \frac{L_x - L_c}{L_c} \times 100 \% $$

where $L_c$ – average root length in the experiment, mm; $L_c$ – average root length in the control, mm. Oats were selected as a test-crop according to МР 2.1.7.2297-07 technique [18]. Oats are an annual monocotyledonous (monocot) plant that has a heightened sensitivity to soil contamination. This bioindicator is characterized by rapid seed germination and almost 100 % germinating ability which perceptibly declines in the presence of contaminants. In addition, stems and roots of this plant under the influence of pollutants undergo significant morphological changes (growth inhibition and curvature of plants, decrease in root length, as well as in number and mass of seeds). Oats withstand high soil acidity [17]. The roots of oats have a large number of root hairs whose surface makes more than 90 % of the entire root system. Such hairs are of increased activity, so the oats root system is remarkable for its high absorption capacity, which to a great extent causes indicative capabilities of oats. Oats, as a bioindicator, are also convenient because the action of stressors can be studied simultaneously with a large number of plants having a small workplace area.

where: $Q_i F_i$ – frequency of occurrence of each species; $F_i$ – the quantity of each species.

60 species of trees were examined in the study areas (15 trees in each study area on average), and 13 most common lichen species were identified. When determining the species of lichens, there were used photos obtained in places of growth and electronic determinants [19]. In compliance with the scale [10] lichens which were found in the study areas, were classified according to the classes of toxic tolerance (Table 1).

### Table 1

| Sensitivity | Lichen                   |
|-------------|--------------------------|
| Class S – Sensitive | Caloplaca discolor. Caloplaca marina |
| Class I – Intermediate | Anaptychia ciliaris. Physcia adscenens |
| Class T – Tolerant | Hypotrachyna revoluta. Parmelia acetabulum |

Percentage ratio of the classes of toxic tolerance to SO2 in lichen species found in all the study areas is shown in Fig. 3.

The highest percentage belongs to lichens of T (Tolerance) class – 60 % that indicates an increased content of sulfur oxides in the atmospheric air of the study areas. Fig. 4 graphically demonstrates the average projective cover of lichens in the study areas, where the numerical value characterizes the level of contamination: the higher the value, the lower the pollution level is.

Having analyzed the data obtained in the study, we can draw the following conclusions. The lowest number of lichens is found in the section along M-03 highway. These lichens refer to the class of Tolerant. Sensitive and Intermediate species are not available. The score on the Brown-Blanche scale is 2.

In the sections along M-02 highway, the projective cover level is 42 % higher, and in the sections along H-07 and H-12, it 200 % and 267 %, respectively, exceeds the...
M-03 indicators. That makes it possible for these sectors to be reported as less polluted and to score them as high as 4 on the Brown-Blanche scale.

The results of lichenological studies and the acquired estimated values are shown in Table 2.

### Table 2

| Section | Polluted area (on Brown-Blanche scale) | Average projective cover, % | Assessment of pollution | Index of atmospheric purity I.A.F. | Approximate concentration of SO₂ in the polluted area, mg/m³ |
|---------|---------------------------------------|-----------------------------|------------------------|-----------------------------------|-------------------------------------------------------------|
| M02     | available crustose lichens             | 17                          | Medium                 | 0.6                               | 0.05–0.2                                                    |
| M03     | on the north side, the greenish algae deposit | 12                          | Severe enough         | 0.4                               | 0.3                                                         |
| H07     | available crustose lichens             | 24                          | Medium                 | 1.8                               | 0.05–0.2                                                    |
| H12     | available crustose lichens             | 32                          | Medium                 | 1.2                               | 0.05–0.2                                                    |
| P44     | available foliose lichens              | 40                          | Not great              | 3.2                               | <0.05                                                       |

Note. Maximum permissible concentration of SO₂ is 0.05 mg/m³

6.2. The results of soil phytotoxicity acquired by germinant method. Soil samples from five study areas were selected (Fig. 1). Soil specimens were taken at a 5 m distance from the road. All the samples were selected under the same weather conditions. Soil sampling was carried out according to DSTU ISO 10381: 2004 [20]. Selected samples were numbered and registered. The soil type was defined according to [21] as grey forest. The average height of seedlings during the experiment is shown in Fig. 5.

Throughout the vegetation period, phenological observations were being carried out. Photographs of plants were taken at different stages of growth. Phenological observations are necessary and very important in this experiment. Their purpose consists in differentiation in the growth and development of plants during the period of vegetation in different soil samples, determination of the occurrence time of plant development phases. Phenological observations help to explain positive and negative changes in the development of the crop under investigation. Measurement results are shown in Fig. 5.

The results of phytotoxicity effect calculation are respectively (2) presented in Fig. 6 in the form of diagrams. The phytotoxic performance is considered to be proven if the phytotoxic effect (FE) makes 20 % or more. In our experiment, the phytotoxic effect in all the samples except one (from P44 road segment) is higher than 20 %. But the highest reading of 58 % and 52 % corresponds to the sections along the M03 and M02 highways, therefore, phytotoxicity in these samples is proven.

It is obvious that the phytotoxic effect is directly proportional to the traffic intensity (vehicle density), and accordingly to the road category. But there arises a question why, with rather considerable differences in traffic intensity on roads of state and interstate significance (Fig. 1), the calculated phytotoxicity values have a smaller difference. In our opinion, another parameter that affects the pollution of roadside ecosystems by means of motor transport emissions is the condition of road surface, i. e. the presence of dents and pits.

Unsatisfactory condition of the road surface entails changes in vehicle running parameters. Drivers have to go at a low speed, often slowing down. Such changes increase emissions of hazardous substances containing exhaust gases [22].
The concentration of sulfur dioxide is lower than the maximum permissible. Along the roads of national importance H07 and H12 this figure was 25 % and 34 %.

The research has shown that the impact on roadside ecosystems depends on the category of a highway, as well as its technical condition. The impact level is higher on the roads with busy traffic and areas with poor technical condition.

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Forced ventilation of tanks

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Analysis of the technogenic load on the environment during forced ventilation of tanks

StORAGE tanks for oil products are environmentally hazardous sources of anthropogenic impact on the environment, acting as objects of uncontrolled emissions of steam-air mixtures or vapor-gas-air mixtures and spills of oil products, followed by fires and explosions. The environmental relevance of storage is essentially dependent on its potential to pollute the environment and on the physical and chemical properties of the stored substances. Petroleum tanks are used on the farm to store gasoline and diesel fuel. Properly designed petroleum storages must prevent leaks and the potential contamination of soils, surface water or groundwater. The analysis of the sources of environmental impact during the operation of the reservoirs indicates that the vertical steel tanks, even during normal operation, are environmentally hazardous.

Preparation of tanks with residues of petroleum products for fire repair works is one of the most complex and environmentally hazardous technological operations in the process of exploitation of tanks. Fires and explosions on reservoirs from flammable substances and flammable liquids often occur during cleaning and preparation for repairs, and in the course of repair work directly [1]. The share...