Green plantations as biological protection of the atmospheric environment from the negative impact of the highway

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Abstract. Nowadays, the most widespread and significant source of air pollutants is highways and road vehicles. The number of road vehicles in the world has already exceeded 1 billion units and continues to grow steadily. Unsatisfactory road conditions promote increased emissions of harmful substances into the atmosphere which has unfavourable impact on the environment. There are several ways to reduce the negative impact of pollutants from road vehicles on atmospheric environment, including planting the roadside area. Eighty-five cross-sections of the highways in different climatic zones of Ukraine were selected for measurements of the concentration of pollutants in the air in the right of way (ROW) depending on the composition of the traffic flow, traffic volume, geometric parameters of the road and the presence of green plantations were performed. The results show that NO₂ and dust increased in all sites. The green plantations can effectively reduce the concentration of harmful emission up to 70%, dependent on plant species and green plantation width.

1. Introduction
Among the anthropogenic sources of pollution in urban areas, transport holds the second place in the cities of Ukraine after the industry which is typical for other developed cities in the world. Huge amounts of dust, soot, exhaust gases, lubricants, heavy metals and hundreds of other substances are released in the environment. In addition, physical factors such as noise [1], vibration, electromagnetic fields, etc., have a significant impact on ecosystems, they are not always directly perceived and are often ignored in practical environmental studies [2].

Emissions of exhaust gases from road vehicles are the main source of pollution of atmospheric air in the roadside area [3]. Pollutants from vehicles that appear on the roads are spread through the roadside area, sidewalks, available spaces between green plantations and houses located along the street inside the quarters and courtyards of the residential area. There is a complicated mechanism for the formation of bioclimatic and ecological conditions due to the interaction of vehicles with the road and its infrastructures (traffic lights, roadside, etc.).

Atmospheric air is one of the most important natural resources without which life on the Earth would be completely impossible. Therefore, protecting the atmospheric air and reducing the negative impact on it is one of the key tasks of the environmental protection science.

Unsatisfactory road condition contributes to increased emissions of harmful substances into the atmosphere. Thus, due to the low technical level of highways, the accident rate of individual sections, the overload of roads in approaches to cities, speed opportunities of road vehicles are not implemented,
fuel is consumed in 1.3-1.5 times more, repairs and maintenance costs of the roller stock are increased in 2.5 -3.4 times, the service life of road vehicles is reduced by 20-30%.

Traffic emissions are highly affected by riding qualities which include the following:

road – relief, width of the carriageway, type and condition of the road surface, coefficient of tyre grip and evenness of pavement, condition of the roadside, availability and quality of the elements of engineering equipment;

transport – type of cargo, traffic volume, traffic density, speed mode;

weather and climate - visibility, precipitation, temperature, pressure and air humidity;

operation culture - level of works organization and management, qualification and discipline of drivers, material and technical base, quality of operational materials.

Road conditions are usually divided into permanent and variable. The permanent include the composition of the road pavement, the route plan, the longitudinal and transverse profile, the width of the carriageway, crossings and side roads. The variable road conditions include the degree of evenness of road pavement, tyre grip coefficient, visibility of the road, etc.

There are several ways to reduce the negative impact of pollutants from road vehicles on atmospheric air. The most environmentally friendly among them is the planting of the roadside area. Therefore, it is expedient to study the green plantations as the biological protection of the air environment from the negative impact of the road.

Green plantations on highways perform the following functions [4]:

• protection of roads and their structural elements from the influence of adverse weather and climatic factors;

• reduction of atmospheric air pollution during reconstruction, overhaul and operational maintenance of highways;

• reduction of pollution of the adjacent territories from harmful emissions of vehicles;

• snow retaining which has a positive impact on adjacent agricultural territories;

• protection against soil erosion;

• improvement of the microclimate

• development of elements of comfort and architectural-aesthetic design of the road;

• development of conditions for better provision of traffic safety for vehicles and people;

• proving the noise protection;

• providing the visual guidance for drivers.

Green plantations, being a part of transport facility, must emphasize the specificity of the object and improve its perception. The purpose of green plantations is to create and maintain favorable and comfortable conditions for road users and residents of roadside areas.

To create and maintain favorable and comfortable conditions for road users and residents of roadside areas, during choosing the plant type for green plantations in the ROW, it is necessary to take into account the shape of the crown, the height, the bloom of the summer and autumn color of the leaves, the quality of the soil, the color of flowers and fruits. All these factors must create the harmony of the combination with the environment or the contrast to it depending on the purpose of the plantations.

In this study, we selected 85 cross-sections of highway in different climate zones of Ukraine, and measured concentrations of pollutants, road traffic and green plantation conditions. The main aim is to compare 1) the effects of different plants to road traffic emissions; and 2) the survival ability of different plants near roads.

2. Materials and methods

During the measurement of the pollutants concentration in the air within the ROW, the field and instrumental research were conducted.

During field research, the parameters of the relief, the quantitative and qualitative state of green plantations and the width of green plantations were determined.

Instrumental research included the following measurements:
–temperature, humidity, atmospheric pressure and air velocity;
–concentration of carbon oxide (CO), nitrogen dioxide (NO2) in atmospheric air;
–concentration of dust that is undifferentiated by composition in the atmospheric air;
–distance from the edge of the carriageway to the green plantations;
–traffic volume and composition.

Measurement of concentrations of carbon dioxide CO, nitrogen dioxide NO2 in the atmospheric air was carried out by a gas analyzer which is based on the electrochemical principle.

Determination of the concentration of dust that is undifferentiated by the composition (further - dust) in the atmospheric air was carried out by gravimetric method in accordance with RD 52.04.186 [5]. Sampler and electronic weighing scales were used for sampling the dust.

Measurement of the distance from the edge of the carriageway to the green plantations was performed by the tape measure.

One of the studied cross-section (Figure 1) is road section km 24+000 (Figure 2) of highway of international importance M-07 (Kyiv-Kovel-State border of Poland).

Inspection was carried out on 17 September 2018 at the following meteorological conditions: duration of inspection - 09 hour 30 min, temperature - 20.0±0.2 °C, relative humidity - 56±1 % and air velocity - 0.2-0.4 m/s.

Data on the composition and average daily traffic volume is shown in Table 1, as well as the results of instrumental research of concentrations of CO, NO2 and dust in the atmospheric air are shown in Table 2.

According to the results of field inspections, measurements of meteorological characteristics of the air and measurement of pollutant concentrations in the air in the ROW, recommendations for choosing the type of green plantations to reduce atmospheric air pollution during construction, repair and operational maintenance of roads were developed.

![Figure 1. Cross-section of road section of highway M-07 km 24+000.](image-url)
**Figure 2.** Green plantation along highway M-07 km 24+000.

**Table 1.** Traffic volume and composition.

| Traffic composition | Traffic direction |
|---------------------|-------------------|
|                     | Kyiv   | Bucha  |
| Cars                | 110    | 114    |
| HGV                 | 34     | 36     |
| Buses               | 10     | 6      |
| Mini buses          | 36     | 24     |
| Motorcycles         | -      | -      |
| Traffic volume vehicles/per hour | 380 | 360 |

**Table 2.** Pollutant emissions.

| Place of measurements | Concentration, mg/m² | CO | NO₂ | dust |
|-----------------------|----------------------|----|-----|------|
| № of measurement points | Distance from the edge of the carriageway |    |     |      |
| 1                     | 0 m                  | 4.0| 1.3 | 0.9  |
| 2                     | 5.3 m                | 3.1| 1.1 | 0.7  |
| 3                     | 0.5 m after the plant crown | 0.5| 0.5 | 0.2  |
| 4                     | 0                    | 4.3| 1.5 | 1.0  |
| 5                     | 7.2                  | 2.1| 1.0 | 0.6  |
| 6                     | 0.5 m after the plant crown | 0.5| 0.7 | 0.2  |

3. Research results

Green plantations that retain the dust and reduce the air pollution level are shown in Table 3. The Table 3 shows that the effectiveness of dust protection properties of different species of plants is not the same and depends on the structure of the tree and its wind protection ability. In particularly, the rough leaves (elm) and the leaves covered with thin filaments (lilac, bird cherry tree, elder-berry) retain the dust better than the smooth leaves (maple, ash-tree, staff tree).

Leaves with felted puffiness retain the dust a little bit differently from the leaves with wrinkled surface, but they are poorly cleared by rain. Sticking leaves at the beginning of the vegetation have high dust retaining properties but later lose them. Dust deposits in needle-leaved species per weight unit of pine needles are in 1.5 times more than per weight unit of leaves, and dust protection properties are retained all the year round.
Table 3. Amount of deposited dust on the leaves surface of different plant species.

| Plant                        | Total leaf area, m²/per plant | Total amount of deposited dust, kg/per plant |
|------------------------------|--------------------------------|--------------------------------------------|
| **Trees**                   |                                |                                            |
| Ailanthus                   | 208                            | 24                                         |
| False acacia (Robinia pseudoacacia) | 86                              | 4                                          |
| Elm pinnately branched      | 66                              | 18                                         |
| Scotch elm (Ulmus glabra)   | 223                            | 23                                         |
| Gleditschia                 | 130                            | 18                                         |
| Willow (Salix sp.)          | 157                            | 38                                         |
| Field maple (Acer campestre) | 171                            | 20                                         |
| Caroline poplar (Populus x Canadensis) | 267                        | 34                                         |
| Mulberry-tree (Morus sp.)   | 112                            | 31                                         |
| Green ash tree              | 195                            | 30                                         |
| European ash tree           | 124                            | 27                                         |
| **Shrubs**                  |                                |                                            |
| Yellow acacia               | 3                              | 0.2                                        |
| Louseberry                  | 13                             | 0.6                                        |
| European privet (Ligustrum vulgare) | 3                           | 0.3                                        |
| Red elder-berry             | 8                              | 0.4                                        |
| Russian olive               | 23                             | 2                                          |
| Lilac                       | 11                             | 1.6                                        |
| Spiraea                     | 6                              | 0.4                                        |
| Spotted grapes              | 3                              | 0.1                                        |

Research results of the green plantations that reduce the pollution of atmospheric air from emissions of exhaust gases of vehicles are confirmed by data from [6] and are shown in the Table 4.

Table 4. Characteristics of green plantations.

| Types of green plantations                          | Decrease in the concentration of exhaust gases, % |
|-----------------------------------------------------|--------------------------------------------------|
| Three-lane strip of foliage tree of line design with a width of 10 m | 40-50                                           |
| Four- lane strip of foliage trees of line design with a width of 15 m | 50-60                                           |
| Four- lane strip of needle-leaved trees of chess design with a shrub of 20 m width | 50-60                                           |
| Five- lane strip of foliage trees of chess design with a shrub of 20 m width | 60-70                                           |

At the same time, it is necessary to ensure survival of green plantations in a contaminated gaseous environment.
According to the test reports and results of measurements, the most common plantations and characteristics by the degree of gas resistance were determined which are shown in Table 5.

**Table 5.** Characteristics of the main species of trees and shrubs by degree of gas resistance.

| Species                     | Degree of gas resistance |
|-----------------------------|--------------------------|
| common pine                 | Very low                 |
| white poplar, field maple   | Low                      |
| fir tree                    | Medium                   |
| European ash, Tatarian maple and Norway maple, balsam poplar, Tatarian honeysuckle, birch bark, field maple, white poplar |                      |
| Larch                       | Strong                   |
| oak tree, green ash, elm, willow, False acacia, lilac, fustic, ash tree, three-thorned acacia |                      |
| fustic, Russian olive, poplar (Caroline, black, balsam), white dogwood, wild rose, Yellow acacia, red dogwood | Very strong |

Our results indicate that, when choosing the species of green plantations in terms of reducing the pollution of atmospheric air, it is expedient to choose species that can efficiently purify the air from harmful gases and dust. When choosing the plants to achieve the highest dust protection effect, it is necessary to take into account their properties [7], for example, varying the size of the area planted, choosing the required density of plantations. Choosing the green plantations that purify the air from harmful gases, it is necessary to take into account the gas-absorbing properties of species of green plantations and the number of leaves [8]. At last, the plants with high resistance to gaseous pollutants should be preferred.

4. Conclusions

In Ukraine and other countries of the world, it is necessary to develop relevant legislation on the use of green plantations to reduce the negative impact on the environment during the construction of new and the operation of already existing highways. It will significantly help to reduce the harmful impact on the atmospheric air and the environment as a whole.

The field survey of the measurements of the pollutant concentrations in the atmospheric air in the ROW depending on the composition of the traffic flow, traffic volume, geometric parameters of the road and the presence of green plantations was carried out.

The results of the research indicate the increase of the permissible concentrations of nitrogen dioxide and dust that are undifferentiated by composition on all cross-sections near the edge of the highway and at the distance of the cut or embankment of the highway.

At the same time, green plantations significantly reduce the concentration of harmful emissions up to 70%. The roadside plants are different in the reduction degree of and resistance to the traffic-related pollutants including dust and gases.

References

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