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# Performance analysis of protective functions of forest plantations of the Lviv railway line (Ukraine)

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**Abstract.** To reduce the harmful impact of railway transport on the environment and ensure environmental safety, railway enterprises develop and implement a wide range of environmentally effective measures annually. First, it concerns the protection of the territories adjacent to the railroad tracks from various types of pollution. These forest plantations are created for the protection of the railroad track from adverse climatic factors, as well as for the reduction of the railway's impact on the surrounding territories – to reduce the various types of pollution, and to protect from adverse aerodynamic effects. In order to investigate the protective properties of forest plantations, we presented their detailed characteristics on the section of the Lviv-Sambir railway line. This is the busiest railway line in terms of the number of trains, which connects the eastern industrial regions of Ukraine with the western part of the European Union. It transports the largest volumes of cargo, including hazardous ones. The effect of afforestation on reducing the heavy metals content in the soil of the impact area of the railway was determined experimentally. In all samples, the concentrations of heavy metals in the soil do not exceed the maximum permissible concentration standards: Cu-100, Zn-100, Pb-30, Cd-3.0 mg/kg$^3$. However, there is a decrease in the heavy metals' content with the distance from the track. Differences in ingredient pollution depending on the placement of plantations were established. Thus, the concentration of heavy metals is higher on average from 2.6% to 29.9% in the areas on the windward side compared to the areas on the opposite leeward side. Therefore, forest vegetation intensively retains heavy metals and performs the function of a filter for the natural environment. Research has established a reduction in the parametric impact of railway transport. The level of protective plantings' effect on noise reduction along railway lines was determined. The highest noise levels of electric trains were determined at 95–94 dBA near the track, at a distance of 50–100 m the noise level remained high at 90–82 dBA, and at a distance of 150–200 m the noise ranged from 86 to 65 dBA; the highest noise levels of passenger trains were determined near the track of 92–91 dBA; freight trains - near the track 93–92 dBA. The dependence of the noise level on the structure and condition of the plantations was determined. Thus, it can be stated that the existing forest plantations perform their phytomelioration functions and reduce the negative ingredient and parametric impact of railway transport. In order to protect the territories adjacent to the railway from pollution successfully, it is necessary to monitor transport sections constantly to ensure the sustainable development of the railway industry.

**Keywords:** railway transport, forest plantations, environment, environmental safety, heavy metals, noise pollution.

## 1. Introduction

The railway is the most promising type of transport nowadays because it optimally combines speed, price, and environmental requirements of society. The total length of the world railway network is 1.2 million km, and the operating length of the main railways of Ukraine is approximately 2.3% of the length of the world's railways. They perform 6% of the world's cargo turnover and almost 5% of the world's passenger turnover. In 2022, military aggression on the territory of Ukraine dramatically affected the trade volume, leading to an unprecedented drop in the railway transportation volume in the last 10 years (Zaporozhets et al., 2017).

Railways are landscape-transforming factors of the environment. The influence of railway transport on the environment is due to the consumption of a significant amount of water, air, fuel, energy, and non-renewable mineral natural resources during the operation of railway transport. There is also contamination with toxic substances of all components of the environment: air, water basins and soils as a result of the operation of transport with toxic substances; burning diesel and coal fuel, using lubricants, etc. In addition, environmental pollution is caused by transporting bulk goods and hazardous substances (waste of various content, rocks), during emergency situations, and using herbicides for unwanted vegetation on the track prism. The most dangerous is the ingress of heavy metals into the ground cover and the poisoning of living organisms. Based on the degree of influence on living organisms, heavy metals belong to the I and II hazard classes and can migrate through plants and animal organisms along the trophic chains into the human body. Heavy metals of the first hazard class (Pb, Zn, Cd), have a neurotoxic effect. In particular, lead causes mental disorders, weak perception and memory, and retardation of children's development. Zinc has a teratogenic and mutagenic effect. Cadmium causes kidney and liver dysfunction. Heavy metals of the second hazard class (Cu, Cr, Ni) have a mutagenic effect and increase cellular permeability (He et al., 2017; Pavlyshina, 2011; Ruda & Boyko, 2020; Yelda, 2015).

There is also significant noise and vibration pollution in areas adjacent to railway tracks. Noise from trains causes negative consequences, expressed primarily in sleep disturbances, feeling sick, changing behavior, increasing the use of medications, etc. The noise of trains interferes with the perception of spoken language more than the noise of road traffic. This is explained primarily by the duration of the noise effect caused by the train. Noise can cause a stressful state characterized by increased activity of the central and autonomic nervous systems (Golia et al., 2021; Lukianchuk & Burmas, 2006; Jeong et al., 2021; Otto et al., 2019; Zukopp et al., 1981).

One of the most effective measures for reducing the negative impact on the environment is green plantings along railway tracks. Forest plantations along the railway have protective, forest improvement, recreational, landscape, and ecological purposes. Forest strips perform nature-protective, environment-transforming, social, and utilitarian functions. The system of forestry measures carried out in forest plantations is aimed at preventing disturbances of the internal ecological balance and maintaining an effective protective structure of forest stands, compliance and harmonizing the coexistence between forest species, forming long-lasting and valuable protection plantations. This is facilitated by scientific research and normative documents created on their basis, rules and recommendations for the maintenance of protective forest plantations of railways. Management of forests along railroads is carried out in accordance with the Forest Code of Ukraine on the basis of forest management by forestry enterprises, the Rules for the maintenance of protective forest plantations of railways. According to Ukrainian Railways (Plakhtiy et al., 2008), sufficient forestry, agrotechnical, reforestation, and protection measures were carried out in the existing forest plantations during the transitional forms of management in Ukraine in recent years. The main principle is to ensure the continuity and permanence of the protective, environmental, health and wellness, and aesthetic function of protective forest strips. This principle is ensured by the timely implementation of a set of organizational measures carried out by the relevant service of the railroad track (Baranovskyi et al., 2021; Chornopyska & Stasiuk, 2020; Kobylkin et al., 2020).

Besides, possible dangerous environmental impact is monitored on the railway. Without an appropriate environmental monitoring study, a dangerous situation will pose a real threat to the health of the population. Ukraine strives to ensure "sustainable development of railway transport", which should be understood as the development that provides economically efficient, socially oriented, and environmentally safe conditions for the provision of railway transport services in the interests of present and future generations.

## 2. Materials and methods

### 2.1. Study area description

For the determination of the heavy metal content in the soil, the method of atomic absorption spectrometry is used. It consists of making an extract from the soil or plants' ash solution, in which the element content is determined by an atomic spectrophotometer. Atomic absorption spectrophotometer is a laboratory stationary indicating and self-recording device of periodic action. The determination of heavy metal is carried out according to the approved "Methodology of measurements using the C 115-M1 atomic absorption spectrophotometer" (Maksimtsev et al., 2021; Trokhymenko et al., 2012). For the pollution level determination sampling was carried out at different distances from the source of pollution, namely (Fig. 1):

- Sample No. 1 to assess the background heavy metals content at a distance of 250 m from the railroad;
- Sample No. 2 – at a distance of 200 m from the railroad;
- Sample No. 3 – at a distance of 150 m from the railroad;

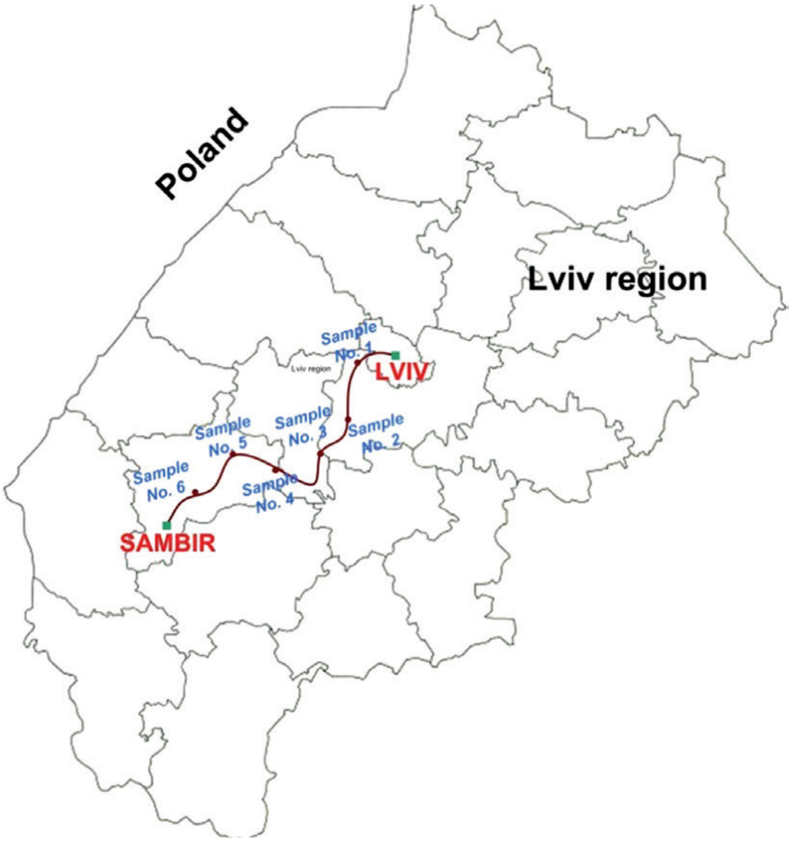


**Figure 1.** Sampling site in the protective afforestation of the Lviv-Sambir railroad track, Lviv region, Ukraine

– Sample No. 4 – at a distance of 100 m from the railroad;
– Sample No. 5 – at a distance of 50 m from the railroad;
– Sample No. 6 – at a distance of 5 m from the railroad.

### 2.2. Soil sampling

Soil samples were taken at a depth of 0–5 cm. The total weight of an average sample is 1 kg. Sampling was carried out in cloudy-weather conditions on October 10, 2021, during the period of the end of vegetation of grass and the greatest accumulation of heavy metals in the soil. The soil selected for analysis was air-dried for several days. Drying helps stop microbiological processes that lead to changes in the content of biogenic elements and organic compounds. Selected samples were stored in dry, dark and well-ventilated place prior to the laboratory examination. The level of heavy metal pollution was studied in the right (windward) and left (leeward) guardrails of the railway track. Air-dry soil weighing 600–750 g was placed on clean paper and plant roots, pebbles and other inclusions were removed. Large lumps of soil were ground in a porcelain mortar and mixed with the main mass. The average soil sample was prepared for analysis by quartering i.e. thoroughly mixed sample was placed on clean paper in the form of a square and divided diagonally into four equal parts with a spatula. The two opposite parts were discarded, and the other two were combined, mixed, and a sample was taken from this soil for analysis. For a homogeneous sample, the average sample was sifted through a sieve with a hole diameter of 0.25 mm before analysis. Lumps that remained on the sieve were ground in a mortar and sieved again.

Sifting through soil sieves was carried out with a closed lid and it was opened no earlier than 2–3 minutes after the end of sieving. This lets the dust settle and not lose the most active part of the soil – the silty fraction. Such soil preparation is performed for gross analysis. When preparing the soil for extraction, it was enough to sift the sample through a sieve with a hole diameter of 1 mm. Heavy metal ions were determined complexometrically in the filtrate after the separation of secondary oxides. The most dangerous elements were determined: lead, cadmium, zinc (first hazard class), copper (second hazard class).

### 2.3. Measurement of the noise effect

Establishing the noise effect involves determining the noise permeability of forest strips and dispersing sound streams by plantations. The research was conducted using computer software, namely the Sound meter 2.4 program and the Sven sound-sensitive microphone. We used an auxiliary microphone to ensure data accuracy. The sound meter is installed at a distance of 1 m from the ground, taking into account the topography of the territory. Only flat areas were chosen for the study to prevent a change in the turbulent regime. Measurements were made in the forest strip in a leafless state in March and in a leafy state in May. The noise absorption effect was determined separately for each source of acoustic pollution: electric trains, passenger, and freight trains. The sound level was measured at different distances from the railroad. To determine the background value – 2 m from the track – point 1; at a distance of 5 m – in front of the forest strip – point 2; in the lane – at a distance of 50 m from the track – point 3; in the lane – at a distance of 100 m from the track – point 4; in the lane – at a distance of 150 m – point 5, and behind the lane – at a distance of 200 m from the railroad – point 6. The measuring of the noise level from electric trains was carried out under the conditions of one noise source moving at a speed of 60 km/h, and from freight and passenger trains at a speed of more than 90 km/h.

## 3. Result and discussion

### 3.1. Analysis of protective functions of forest plantations

The first forest plantations at the Lviv-Sambir section (Lviv railway, Ukraine) with tree species were planted in 1960–1970, however they appeared to be different than today as the plants spread over the larger territory. The basis of forest plantations comprised of forest species with the relevant forms of trunk with a well-developed crowns which, according to their bio-ecological features, are relevant to the habitat conditions. It is vital to consider that protective forest plantations of railways near populated areas belong to the green zone (Skrúcaný et al., 2018; Sun et al., 2020; Zaporozhets et al., 2017; Zelenko et al., 2019).

According to geological and structural peculiarities, the studied terrain belongs to Pre-Carpathian artesian basin. The territory is designated by homogeneity of hydrogeological conditions of distribution of aquifers with high mineral concentration. Drastic difference in effect of hydrogeological conditions is observed between plain and undulating terrain. The main river is the Dniester, namely its tributary. The level of groundwater is at 0.5 to 7 m. Hydrological regime varies throughout a year and depends on precipitation regime. Annual level fluctuation is characterized by spring upraise caused by snow melting and summer rain high water. Summer high water usually exceeds spring high water and takes several waves. Autumn period is characterized by stable and low levels. In winter, as a result of thaw, considerable rising of the water is occasionally observed. Water level fluctuation throughout a year and during several year period are rather significant – 2.5–4.5 m. During the years abounding in water, their height reaches 5.5–6.0 m above the baseflow. Distribution of runoff during the year is uneven and depends on precipitation level at river basins, air temperature, and anthropogenic factor. The most part of the runoff (40–50%) is formed during spring period (March-May), 30–40% establishes during summer-autumn period and 10–20% of annual runoff arises during winter. Module of average runoff makes 7.0 l/sec/km$^2$ and average annual runoff rate of water is 5–30 m$^3$/sec. Soil cover includes prevailing grey and light-grey puddled, meadow soils, characterized by superficial humus horizons of 10–12 cm, humus content is 3%, soil profile is poorly structural (Karabyn et al., 2019; Posokhov et al., 2019; Tomczyk-Wydrych et al., 2021).

The section of Lviv-Sambir rail is located in the south-west part of Lviv region and it is characterized by the same natural and climate conditions as Sambir district in Lviv region (Fig. 2). The climate of the territory is moderately continental, with mild winter and wet prolonged spring, warm rainy summer and relatively dry warm autumn. During the year western and northern-western winds are observed. Average air temperature during the warmest month (July) is +18°C, and during the coldest month (January) is +4°C. Unfavorable natural conditions of the studied area include karst, linear erosion, landslides, flooding, wetlands, mudflow, etc. Their activation continues, as a result of which increase of technogenic destabilization of geological environment of the region in general take place. Protective forest plantations at the section of Lviv-Sambir rail are territories of inconsiderable environmental risk level.

The green areas adjacent to the section of the Lviv-Sambir railway line are in satisfactory condition. Depending on the location, forest plantations have a different structure, that is, the structure of the longitudinal profile, which determines its aerodynamic properties. Forming a certain structure of the forest strip, they are non-blowing or blowing. The non-blowing (tight) design of the strip is created in such a way that the main mass of wind flows around the strip from above, and no more than 10% of the wind flow passes through it. Such plantations are complex multi-tiered ecosystems with undergrowth, without openings within the entire vertical profile, they protect railway tracks from adverse external factors, such as dry winds, and dust storms, retain meltwater, and soften the action of wind masses. The blowing design provides for evenly spaced openings with an area of 15–30% along the entire longitudinal profile of the strip. The main part of the airflow passes through the openwork scheme, and the rest flows around it from above. The width of such strips is 15–20 m and they are formed in areas with a small influence of wind flow. Blowing forest


**Figure 2.** Geographical position of Lviv-Sambir railway lines in Lviv region, Ukraine

strips have a dense structure in the upper part of the vertical profile and large clearances between the trunks in the surface part. These are simple 1–2 tier plantations without bushes or with bushes less than 1 m high. Openwork forest strips are complex 3–4 tier plantations with undergrowth, and evenly spaced openings within the entire vertical profile. The inspected lanes on the section of the Lviv-Sambir railway line are multi-row with a width of 200 m on both sides of the track. The height of trees in the protective forest strip is characterized by a lower height than those growing in the forest massif (Fig. 3).

The main tree species performing the protective function in the belt include *Populus nigra* L., *Betula pendula* Roth., *Acer tataricum* L., *Carpinus betulus* L., *Alnus incana* L. Moench, *Fraxinus excelsior* L. Among related species ensuring better growth of the main species and better protection are: *Prunus*

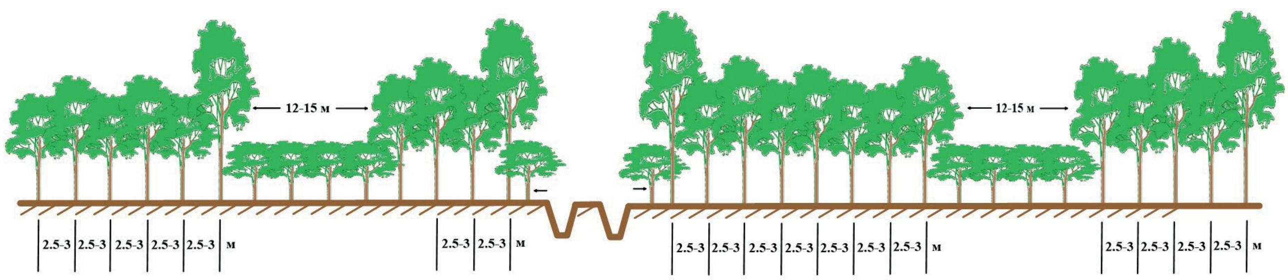


**Figure 3.** Scheme of vertical structure of protective forest plantations at the area of Lviv-Sambir railway line, based on (Pohrebennyk et al., 2016)

*avium* L., *Populus tremula* L., *Ulmus glabra* Huds., *Crataegus oxyacantha* L. The main forest formation species is *Quercus robur* L. Afforestation has sufficient undergrowth. The young generation of forest species growing under the forest canopy or logging is able to reach the first plantation layer, replacing old timber stands. The undergrowth contains *Corylus avellana* L., *Lonicera xylosteum* L., *Euonymus verrucosa* Scop., *Sorbus aucuparia* L. (Borda-de-Água et al., 2017; Malovanyy et al., 2022).

### 3.2. Analysis of the impact of harmful substances

At the stage of the initial emission of harmful substances a pollution area is formed under the influence of meteorological and landscape factors. The most crucial landscaping factors are the earth's surface, type of vegetation, and hydrographic network, which are collectively united by the term "underlying surface". All physical processes taking place at the lower atmospheric layer occur under the influence of the underlying surface. Sedimentation of aerosol particles depends on gravitation forces and turbulent mixing of air based on their size. The size of particles varies from 0.001 to 800 microns. The behavior of light small particles (up to 200 microns) near the air-ground interface is mostly determined by turbulent diffusion, thus the speed of their sedimentation varies based on the kind of underlying surface. Among all the elements of the underlying surface, forest plantations cause the greatest effect on the turbulent structure of the wind. Transformation of flow structure consists of the decrease of vertical pulsation of the wind speed and the creation of smaller whirlwinds under the influence of forest.

Sedimentation of aerosol particles is influenced by the airflow transformation. Thus, forest plantations perform a crucial role in the formation of the pollution area. They are filters-accumulators of heavy metals and radionuclides. The results of the latest research show that in the case of high pollution degree, considerable variability of pollution density of soil within forest plantations is observed even within a section or block. The pollution diversity can be explained by the heterogeneity of forests and their local influence on the air transfer rate of harmful substances and rainfall intensity.

Land-based vegetation is the first screen to retain pollution, namely heavy metals. Retention of precipitated hard aerosols on plants and their further losses depend on several factors, in particular: phytomass per unit area of surface; leaves shape, size, orientation, and other land-based plant organs; properties of their surface; wind speed during and after particles emission; the size of aerosols particles and amount of precipitation; relative humidity during precipitation, etc. (Lukianchuk, 2020).

### 3.3. Vegetation analysis

For instance in order to characterize the vegetation cover ten samples were taken. Each sample plot has its typical taxonomic peculiarities. A study of the phytomass of vegetation cover was carried out at the end of the vegetation period (August-September) at the belt with a width of 200 m. According to the results of the research was found that usually tree, tree-shrub, and meadow herbs grow under the tree-shrub canopy (Fig. 4).

**Figure 4.** Herbaceous vegetation alongside the Lviv-Sambir railroad

Main dominants of herbaceous layer include the following species: *Aegopodium podagraria* L., *Asarum europaeum* L., *Stellaria holostea* L., *Galium odoratum* (L.) Scop., *Oxalis acetosella* L., *Athyrium felix-femina* (L.) Roth ex Mert., *Geum urbanum* L., *Hepatica nobilis* Mill., *Poa annua* L., *Polygonatum odoratum* (Mill.) Druce, *Dryopteris filix-mas* (L.) Schott, *Equisetum sylvaticum* L., *Lysimachia nummularia* L., *Achillea millefolium* L., *Urtica dioica* L., *Veronica officinalis* L., *Carex brizoides* L., *Primula veris* L., *Glechoma hederacea* L., *Trifolium pratense* L., *Trifolium repens* L., *Taraxacum officinale* Wigg., *Vicia cracca* L. On the territory of Ukraine, untimely and irregular cleaning of the roadsides of railroad leads to appearance and active reproduction of hazardous poisonous perennial species *Heracleum sosnowskyi* Manden., which is a part of Umbelliferae family (Apiaceae) and belongs to the category of active invasive species. Plant sap contact with the skin may lead to severe burns. Especially it is dangerous during spring flowering (Lukianchuk, 2016; Melnyk et al., 2022).

### 3.4. Analysis theavy metals content in the soil of protective forest belts

The research showed a very low heavy metals' content in the soil of protective forest belts at all studied collection points. Each studied sample did not show an excess of maximum permissible concentrations (MPC) for Cu – 100; Zn – 100; Pb – 30; Cd – 3,0; mg/kg. However, there are differences in the accumulation of heavy metals depending on the location of the strip on the windward or leeward side. The results of measuring the heavy metals content in the soil on the right side of the track, which is upwind, are shown in Figure 5. The results of the measurement on the left side of the track, which is downwind, are shown in Figure 6.

Figures 5 and 6 show that heavy metals' content in the soil does not exceed MPC. The content of all heavy metals varies depending on distances from the track surface and depending on the sides of the stripes. The only element – cadmium did not show variability in values and was at the level of 0.01 mg/kg, which is also within the regulatory limits. It can be seen from the graphs that there is a significant difference in the content of heavy metals with the distance from the railway track, as shown in Tables 1, and 2. Thus, forest plantations perform their phytomeliorative function and reduce the negative impact of railway transport on the adjacent territory.

As we can see, the strip on the left side is much more effective than the opposite one, on average by 10–5%. Taking

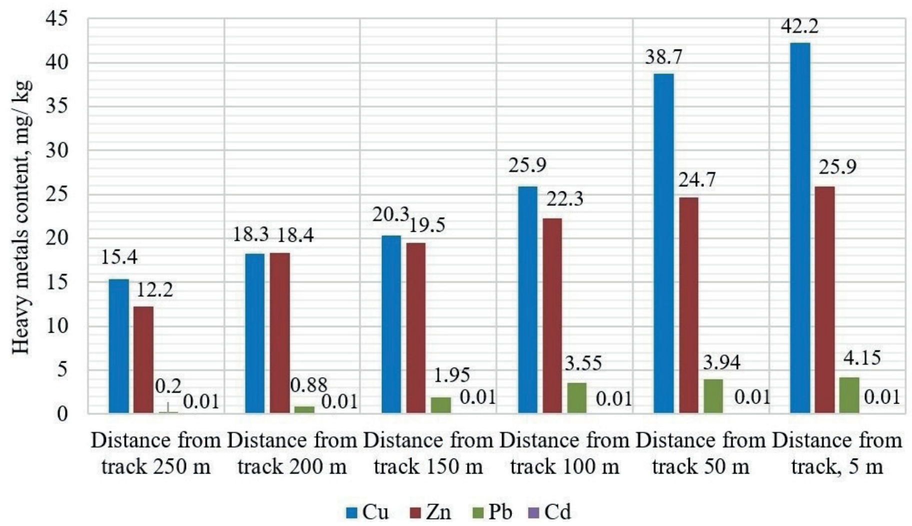


**Figure 5.** Heavy metal content in the soil at the right side of the railroad

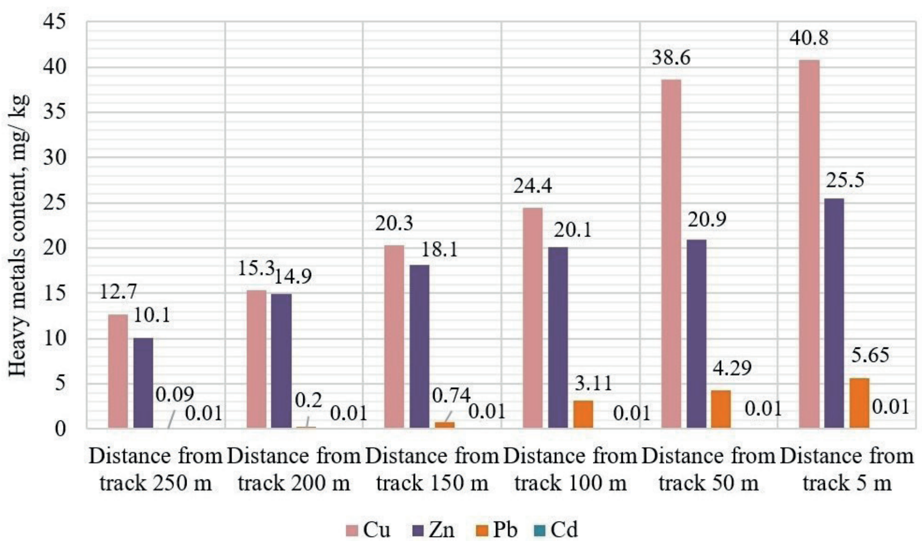


**Figure 6.** Heavy metal content in the soil at the left side of the railroad

**Table 1.** The heavy metals' content depending on the distance from the track at the right side, %

| Heavy metal | *Distance from the track, m* | | | | |
|---|---|---|---|---|---|
| | **250** | **200** | **150** | **100** | **50** |
| Cu | 63.5 | 56.8 | 51.9 | 38.6 | 8.3 |
| Zn | 52.9 | 28.9 | 24.7 | 13.9 | 4.6 |
| Pb | 95.2 | 78.8 | 53.0 | 14.5 | 5.0 |
| Average value | 70.5 | 54.8 | 43.2 | 22.3 | 5.9 |

**Table 2.** The heavy metals content depending on the distance from the track at the left side, %

| Heavy metal | *Distance from the track, m* | | | | |
|---|---|---|---|---|---|
| | **250** | **200** | **150** | **100** | **50** |
| Cu | 68.9 | 62.5 | 50.2 | 40.1 | 5.4 |
| Zn | 60.4 | 41.6 | 29.1 | 21.2 | 18.0 |
| Pb | 98.4 | 96.5 | 86.9 | 44.9 | 24.1 |
| Average value | 75.9 | 66.9 | 55.4 | 35.4 | 15.8 |

into account that the right side of the protective forest strips is windward and receives most of the pollution mass from air vortices during train movement, therefore the heavy metals' content is higher here than on the left side, which is leeward. This is also shown in Table 3. On the windward side, the concentration of heavy metals was higher compared to the opposite leeward side: copper – from 3.7% to 17.5%; zinc – from 1.5% to 17.2%; lead – from 12.4% to 55%.

The conducted measurement in the soil of protective strips on the section of the Lviv-Sambir line showed that heavy metals' content does not exceed the maximum permissible concentrations, however, depending on the distance from the track, the concentration of heavy metals

**Table 3.** Excess of the heavy metals' content on the windward side compared to the windward side, %

| Heavy metal | *Distance from the track, m* | | | | | |
|---|---|---|---|---|---|---|
| | **250** | **200** | **150** | **100** | **50** | **5** |
| Cu | 17.5 | 16.4 | - | 5.7 | 0.3 | 3.7 |
| Zn | 17.2 | 19.0 | 7.2 | 9.9 | 15.4 | 1.5 |
| Pb | 55.0 | 77.3 | 62.1 | 12.4 | - | - |
| Average value | 29.9 | 37.6 | 34.7 | 9.3 | 7.9 | 2.6 |

significantly decreases by an average of 70.5% in the right side and up to 75.9% in the left at a distance of 250 m from the track.

### 3.5. Analysis harmful acoustic pollution

One of the most important functions of protective forest plantations on the section of the Lviv-Sambir line is protection from harmful acoustic pollution from trains. We investigated the level of noise-absorbing efficiency of protective forest plantations using an experimental method. The effect of protective plantings along railway lines on the reduction of the noise level consists of the attenuation of sound vibrations at the moment of passing through the plantings.

The results of noise level measurements are presented in Figures 7–8, depending on the type of train and the distance from the railroad.

Minor differences in the noise level were found depending on the state of the plantations. The highest noise levels of electric trains were determined at 95–94 dBA near the

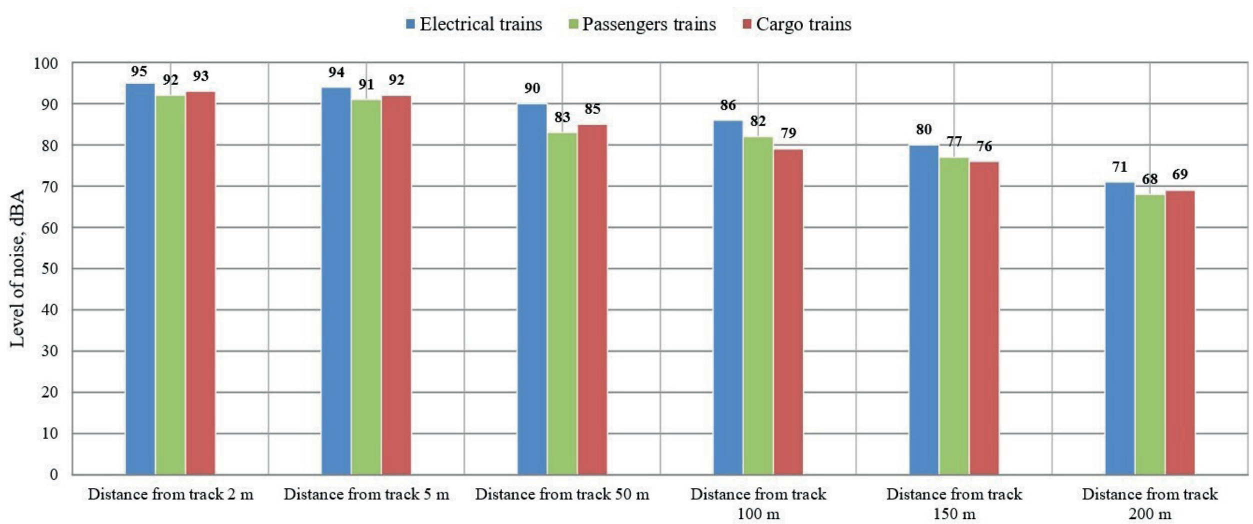


**Figure 7.** Level of acoustic pollution of forest plantations in the leafless state alongside the railroad track

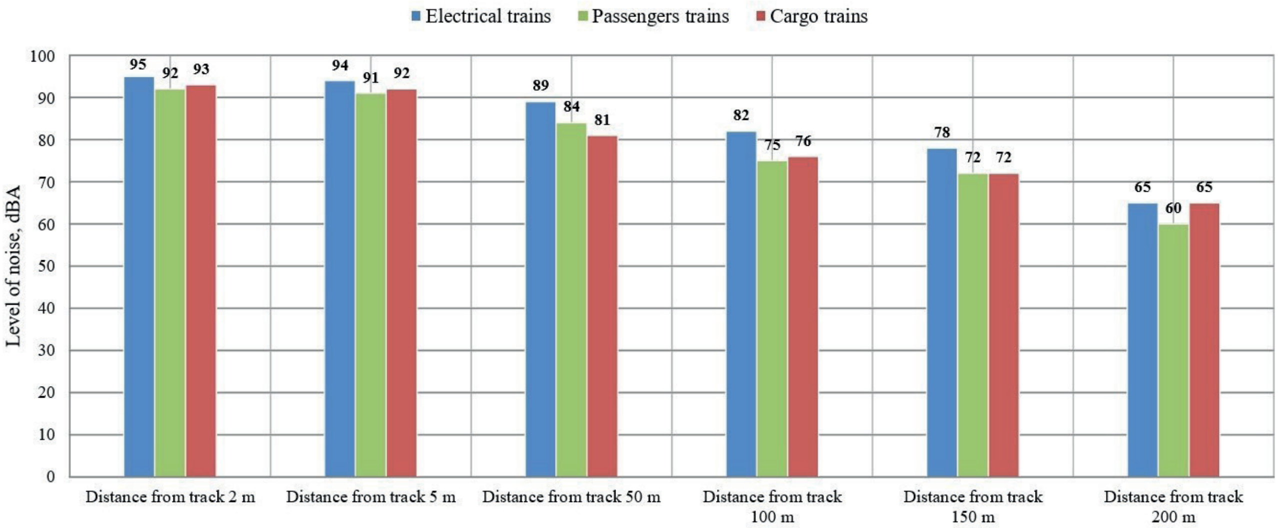


**Figure 8.** Level of acoustic pollution of forest plantations in the leafy state alongside the railroad track

railroad, at a distance of 50–100 m the noise level remained high at 90–82 dBA, and at a distance of 150–200 m the noise ranged from 86 to 65 dBA. The highest noise levels of freight trains were determined at 93–92 dBA near the railroad, at a distance of 50–100 m the noise level remained high at 85–76 dBA, and at a distance of 150–200 m the noise ranged from 76 to 65 dBA. The highest noise levels of passenger trains were determined at 92–91 dBA near the railroad, at a distance of 50–100 m the noise level remained high at 87–75 dBA, and at a distance of 150–200 m the noise ranged from 72 to 60 dBA.

## 4. Discussion

Thus, according to the results of the investigation of soil contamination of protective forest plantations with heavy metals on the section of the Lviv-Sambir railway line, it was established that the heavy metals' content in the soil does not exceed the maximum permissible concentration standards. Low content is safe for nearby agrocenoses and settlements and does not create unfavorable conditions for the growth of soil microorganisms, vegetation, and people.

Pavlyshina (2010) found that the integral pollution index exceeded the permissible concentrations of heavy metals in the crown of the main rock and understory plants by almost 1.5–6.5 and 1.5–4.5 times. We suppose that ground vegetation is the first screen that traps heavy metals. They are so-called filters-accumulators of heavy metals. Retention of solid aerosols settling on plants depends on the surface area of the plantation capable of collecting particles, as well as reducing vertical pulsations of wind speed and forming weaker vortices under the forest canopy. Affecting the deposition of aerosol particles, forest plantations play an important role in the formation of pollution fields. At a high pollution level, there is significant variability in the density of soil pollution in forest plantations even within one block and allocation. Such diversity of soil pollution can be explained by the heterogeneity of forests and their local influence on the pollutants' air transfer and the intensity of rains.

Noise pollution by transport is also a widely discussed issue. A large number of publications are related to the acoustic impact of road transport, but not so much regarding railway. Chorniavska and Hladun (2014) investigated the wind-reducing properties of forest plantations of various structures on the railway transport lines of the Livoberezhny Forest Steppe. Lukianchuk and Ruda (2014) established the dependence of the noise level on the type of train and its speed. The problem of protecting the territories adjacent to the railway track from acoustic pollution has a scientific and technical nature. For many years, work on the creation of anti-noise technical means has been carried out. However, today protective forest plantations still play a dominant role in solving this issue. The green screen of protective forest plantations at the Lviv-Sambir railway line performs the role of noise pollution filter by retaining and partially dispersing it. The conducted research showed a general tendency of noise reduction from all studied sources of noise at 20 dBA, improving comfort in the territories adjacent to the railroad. In the leafy state, the plantations better dispense the sound rather than in the leafless state. Fluctuation of the noise level based on the state of the plantations is 4–6 dBA, which indicates greater noise reduction efficiency of the plantations in the leafy state. However, the decrease in noise reduction efficiency of the plantations when the belts are in the leafless state requires further solutions.

We suggest to complement existing plantings with conifer species – European spruce *Picea abies* (L.) H. Karst and white spruce *Abies alba* Mill. The spruce *Picea abies* (L.) H. Karst is an important forest-forming species that is widely cultivated throughout Ukraine. Although *Abies alba* Mill. is considered to be one of the main mountain afforestation species in Ukraine, it is widely used in the west of the country both for the creation of forest crops and for the landscaping of populated areas. Conifers contribute to noise protection all over the year because multiple reflections and diffuse sounds scattering in their crowns significantly reduce the power of noise. In order to form plantations with sufficiently large shielding properties and sound-absorbing capacity, we suggest creating mixed plantations with dense vertical closeness. It should be a complex tree stand structure – multi-storeyed, with a well-developed edge of shrubs in the form of a hedge. The main species for forest strips on clayey and loamy soils of various genotypes of the Polissya, Forest Steppe and Black Earth Steppe is the pollard oak as a tall and long-lived species with a dense low-hanging dense crown. During the creation of forest plantations, oak is planted in the middle rows, and associate species of trees are planted in the outer rows (maple, tillet, elm-tree, European spruce, silver fir). In the outside rows, it is also desirable to introduce a fruit species as a second admixed tree (common pear, wild apple, walnut or black walnut, cherry). In order to form a dense closeness of plantations, trees should be alternated with the usual accompanying or bushy species. Shrubs should be planted in the space under the shelter, for example, raspberries (*Fructus Rubi idaei*, Baccae *Rubi idaei*) and currants (*Fructus Ribes*). They are partially shade-tolerant, their biological requirements for the soil and climate coincide, and the root systems of crops are not antagonists. Not the last role in the noise absorption process is played by the grassy vegetation. If woody plants can dissipate mostly low-frequency energy, grass plants mainly dissipate high-frequency energy.

Thus, using certain methods in combination with ecological methods of creating forest plantations, it is possible to form highly effective biologically stable protective groups that will qualitatively perform phytomelioration functions.

## 5. Conclusions

Protective forest plantations on a certain part of the Lviv railway effectively reduce soil pollution by heavy metals, and also significantly reduce the noise pollution from the railway. According to the results of research on the determination of heavy metals' contamination of protective forest plantations phytocenosis on the Lviv-Sambir railway line, it was established that the heavy metals content is as follows: Cu – 42.2 mg/kg (MPC 100 mg/kg); Zn – 25.9 mg/kg (MPC 100 mg/kg); Pb – 5.65 mg/kg (MPC 30 mg/kg); Cd – 0.01 mg/kg (MPC 3.0 mg/kg), and it doesn't exceed the maximum permissible concentration in the soil. As it was stated above, the concentration of all stated pollutants in the plants and soil reduces depending on the distance from the railroad, we can state that green plantations retain the spread of pollutants. Affecting the deposition of aerosol particles by the transformation of airflows, forest plantations play an important role in the formation of pollution fields.

The conducted research of the noise level measurement showed general tendency of the reduction of the noise level from all the studied sources of noise at 20 dBA, improving the comfort at the territories adjacent to the railroad. In the leafy state, plantations better dispense the sound rather than in the leafless state. However, the noise reduction decrease by the plantations during the leafless period requires further solutions. It is reasonable to strengthen the plantings with a denser understory of trees and shrubs, which will contribute not only to increasing the various protective functions of the railway forest plantations but also to improving of sound absorption.

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