

Assessment of the impact of railway traffic on the state of plant communities

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Abstract. The article reflects the results of studies on the impact of railway traffic on plant communities. The anthropogenic impact on the environment is complex. Many factors affect the species diversity of the flora near railways in different ways. The accumulation of Cd, Zn, Pb, Cr in plants of *Pimpinella saxifraga* L., *Hypericum perforatum* L., *Trifolium medium* L was revealed. The anthropogenic stress leads to disruption of naturally formed ecosystems, which manifests in a decrease in species diversity, density and biological productivity. As a result of the anthropogenic impact adventitious plants appear, the share of which is 11% of the flora. Research in this area contributes to a deeper understanding of the processes of anthropogenic transformation of floristic complexes and should become the basis for environmental monitoring of disturbed habitats.

1 Introduction

Most of the technologies used by humanity today have anthropogenic impact to one degree or another and lead to ecosystem degradation. Railways are no exception.

A railway is a land corridor alienated from the natural environment, artificially adapted to the movement of trains with specified technical indicators. For the ecological system, it is an alien, aggressive element [1, 2].

Railway traffic has an impact on the environment. The railroad system is seriously facing the challenges of reducing and preventing environmental pollution [3].

The main source of pollution is the exhaust gases of diesel locomotives. They contain carbon monoxide, nitric oxide and dioxide, various hydrocarbons, sulfur dioxide, and soot. Studies have shown that the content of carbon monoxide, nitrogen oxides, sulfur dioxide in the air exceeds the one-time maximum permissible concentration values. This indicates a significant air pollution by exhaust gases of diesel locomotives [4, 5].

In the course of operation of railway transport, synthetic surfactants, oil products, phenols, hexavalent chromium, acids, alkalis, heavy metals, organic and inorganic suspended solids penetrate into the soil. The content of petroleum products in wastewater exceeds the maximum permissible concentration. The soil pollution is much higher in or near the areas where rolling stock is washed and flushed [6].

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The anthropogenic impact on the environment can be local (from a single factor) or complex (from a group of different factors). These impacts, as a rule, are characterized by different environmental hazard coefficients depending on the type of impact and its nature, as well as the object of impact.

Operation of a railway greatly affects the habitat of plants. A railway changes the nearby landscape - it is becoming more open. Maintenance and repair activities affect the nature of the vegetation cover in all functional areas. In the first zone treatment by pesticides is performed, in the second zone burning is used along with pesticides, in the third zone - burning, mowing of the grass stands, cutting down of undergrowth of tree-shrub species. These are just the main activities of the railroad services.

In addition, the impact of many factors affects the species diversity of the flora near railways in different ways: the sources of the formation of the indigenous component are, first of all, roadside biotopes, vegetation of adjacent territories. In case of a very severe pollution of the habitat, the plants stop developing and die [7, 8].

The trends in the railway flora are most clearly “manifested only with the appearance of species alien to the local flora”, while other aspects of the interaction of railways and adjacent natural complexes are ignored [9, 10].

This project is aimed at studying the anthropogenic impact of railway traffic on plant phytocenoses that are located along the railway running through the territory of the Tobolsk industrial site (Tobolsk, Tyumen region, Russia). In this territory, there are railway tracks characterized by a high intensity of railway traffic.

2 Material and methods

The plots for study are located 10 meters along the railway track, at a considerable distance from each other. Plots 1, 2, 3 were located near the SIBUR Tobolsk LLC site, and plots 4, 5, 6 were located near the ZapSibNeftekhim LLC site. These enterprises are part of the Tobolsk Industrial Site (Tobolsk, Tyumen region, Russia). It is noted that the second line of the railway track (LLC ZapSibNeftekhim) is characterized by a heavy traffic.

The selection of geobotanical sites and the description of vegetation were carried out according to the methodological techniques adopted in phytocenology and widely used in geobotanical studies. The main method used in the field part of the research was the method for describing communities of terrestrial vegetation. At the geobotanical sites, the species composition of vascular plants at the time of survey and description was identified.

Dimensions and configuration of the area: $10\text{m} \times 10\text{m} = 20\text{ m}^2$. In total, 6 geobotanical descriptions were drawn up during the field studies [11, 12, 13].

Plot 1. A hypericum and dropwort meadow. Geographical coordinates: N 58. 16.563', E 68.28.446'. The terrain is flat. Total projective cover of the live ground cover: 100%. Grass plants are distributed in strata as follows: Stratum 1 - *Angelica sylvestris* L.; stratum 2 - *Ranunculus polyanthemos* L., *Filipendula ulmaria* (L.) Maxim., *Veronica longifolia* L., *Pimpinella saxifraga* L. *Deschampsia cespitosa* (L.) P. Beauv.; stratum 3 - *Trollius europaeus* L., *Hypericum perforatum* L., *Lathyrus pratensis* L., *Phleum pratense* L., *Agrostis tenuis* Sibth., *Carex pallescens* L., *Vicia cracca* L., *Galium mollugo* L., *Trifolium medium* L. Dominated by: *Hypericum perforatum* L., *Filipendula ulmaria* (L.) Maxim.

Plot 2. A hypericum and clover meadow. Geographical coordinates: N 58° 16.643', E 68° 28.594'. Total projective cover of the live ground cover: 100%. Grass plants are distributed in strata as follows: stratum 1 - *Dactylis glomerata* L.; *Centaurea scabiosa* L., *Veronica longifolia* L., *Picris hieracioides* L., *Pimpinella saxifraga* L., *Centaurea integrifolia* Tausch; stratum 2 - *Agrostis tenuis* Sibth., *Bromopsis inermis* (Leyss.), *Origanum vulgare* L., *Rhinanthus aestivalis* (N.W. Zinger), *Vicia cracca* L., *Trifolium medium* L., *Galium mollugo* L., *Achillea millefolium* L., *Hypericum perforatum* L.; stratum

3 - *Plantago media* L., *Agrostis tenuis* Sibth., *Rumex acetosa* L. Dominated by: *Hypericum perforatum* L., *Trifolium medium* L.

Plot 3. A melilot and wheatgrass meadow. Geographical coordinates: N 58° 16.978', E 68° 28.480'. Total projective cover of the live ground cover: 90%. The grass cover is represented by: stratum 1 - *Centaurea scabiosa* L.; *Picris hieracioides* L., *Artemisia vulgaris* L., *Chamaenerion angustifolium* (L.) Scop., *Cichorium intybus* L., *Melilotus officinalis* (L.) Pall.; stratum 2 - *Phleum pratense* L., *Trifolium medium* L., *Achillea millefolium* L., *Pimpinella saxifraga* L., *Hypericum perforatum* L., *Elytrigia repens* (L.) Nevski; stratum 3 - *Linaria vulgaris* Mill., *Medicago × varia* Martyn, *Berteroa incana* (L.) DC., *Rhinanthus aestivalis* (N.W. Zinger) Schischk. & Serg., *Vicia cracca* L. Dominated by: *Melilotus officinalis* (L.) Pall.

Plot 4. An oxtongue and pimpinella meadow. Geographical coordinates: N 58°16.003', E 68°29.840'. Total projective cover of the live ground cover: 100%. The grass cover is represented by: stratum 1 - *Filipendula ulmaria* (L.) Maxim., *Thalictrum minus* L., *Picris hieracioides* L., *Pimpinella saxifraga* L.; Stratum 2 - *Knautia arvensis* (L.) J.M. Coult., *Hypericum perforatum* L.; stratum 3 - *Stellaria graminea* L., *Rhinanthus aestivalis* (N.W. Zinger), *Agrostis tenuis* Sibth., *Leucanthemum vulgare* Lam., *Galium mollugo* L., *Trifolium medium* L., *Achillea asiatica* Serg.; Stratum 4 - *Alchemilla* sp. Dominated by: *Picris hieracioides* L.

Plot 5. A bentgrass and daisy meadow. Geographical coordinates: N 58° 16.608', E 68°41.664'. Total projective cover of the live ground cover: 100%. The grass cover is represented by: stratum 1 - *Centaurea phrygia* L.; stratum 2 - *Deschampsia cespitosa* (L.) P. Beauv., *Bromopsis inermis* (Leyss.), *Pimpinella saxifraga* L.; stratum 3 - *Equisetum sylvaticum* L., *Achillea millefolium* L., *Phleum pratense* L., *Trifolium hybridum* L., *Trifolium medium* L., *Hypericum perforatum* L., *Agrostis tenuis* Sibth., *Leucanthemum vulgare* Lam.; stratum 4 - *Chamaenerion angustifolium* (L.), *Prunella vulgaris* L. Dominated by: *Agrostis tenuis* Sibth., *Leucanthemum vulgare* Lam.

Plot 6. The geobotanical site is located near the village of Rovdushka, Tobolsk district, Tyumen region. A hypericum and dropwort meadow. Geographical coordinates: N 58° 16.525', E 68° 41.599'. Total projective cover of the live ground cover: 100%. The grass cover is represented by: stratum 1 - *Chamaenerion angustifolium* (L.), *Artemisia vulgaris* L., *Cirsium arvense* (L.) Scop.; stratum 2 - *Filipendula ulmaria* (L.) Maxim.; stratum 3 - *Phleum pratense* L., *Poa pratensis* L., *Pimpinella saxifraga* L., *Stachys palustris* L., *Elytrigia repens* (L.) Nevski; stratum 4 - *Prunella vulgaris* L. Dominated by: *Hypericum perforatum* L., *Elytrigia repens* (L.) Nevski.

Vegetation samples were taken at the studied sites for a chemical analysis.

For the purpose of decomposition, the most common (dominant) types of plants were selected for all plots. The sample (m = 0.3 g) was placed in a plastic tube. Then H₂SO₄:H₂O₂=1:3 was added. The samples were prepared using the speedwave MWS-2 microwave digestion system manufactured by PerkinElmer (USA).

The tube was placed in a microwave oven to decompose the sample using the program recommended by the manufacturer of the oven. The following heating conditions were used: temperature increased to 200 °C within 5 min, keeping for 5 minutes at 200 °C, cooling to 45 °C. The dissolved sample was transferred to a 15 mL test tube. The volume was brought up to 10 mL with distilled water. Then the sample was analyzed.

The quantitative chemical analysis of accumulated heavy metals and trace elements (Cd, Zn, Pb, Cr) in the soil samples and the total plant mass was conducted by the inductively coupled plasma method using the Optima 7000 DV atomic emission spectrometer manufactured by PerkinElmer (USA). Standard solutions of PerkinElmer (USA) were used for calibration.

Before measuring the samples, the required parameters for the measurement were set (the background was measured, the necessary calibration was performed (the minimum and maximum concentration of 0.05-10 mg / dm³).

Statistical processing of experimental data was performed using the Statistica 10.0 software. The arithmetic mean values (X), the standard errors of the arithmetic mean (SD), and the significance of differences in the arithmetic mean by Student's t criterion were calculated. The density of the plant community was determined by counting all individual vascular plants on the test sites. For this purpose, three squares (record plots) of 1 m² were set out within the sites. All grasses on the record plots were cut up to the soil level. In laboratory conditions, the phytomass was sorted by species. Then, the number of shoots was counted [14].

The biological productivity is the ability of living organisms to create, preserve and transform the organic matter. The productivity of a biological community is the amount of organic matter synthesized per unit time and unit area. The biological productivity of a plant community is composed of products of individual plant species making up this community or, more precisely, their coenopopulations. Thus, the biological productivity of individual plant species making up the plant community is the rate of phytomass accumulation over a certain time interval [14,15].

The grasses cut from three record plots were packaged in separate labeled bags. The bags were hermetically sealed to prevent evaporation of water. In laboratory conditions, the phytomass was weighed. It was dried in the open air, and the air-dried phytomass was weighed again. The collected material also served as the basis for calculating the oxygen productivity.

3 Results

Plant communities near the railway are characterized by diversity in species composition and structure. As a result of the analysis of the examined plots, forty-five species of vascular plants were identified.

It was revealed that in areas with heavy traffic, the number of species is significantly less - 4 (14), 5 (14), 6 (13). This can not be said about areas with less railway traffic - 1 (15), 2 (17), 3 (15) - but this difference is insignificant.

The areas with a wide embankment (1,2,3) differ in the greatest variety of species; the nature of the vegetation cover of the surrounding area, near the railway track, also has an effect. Plants growing on railway embankments are evenly distributed by ecological-coenotic groups. Many eco-coenotic groups include a small number of species; therefore, it is convenient to combine them into ecological groups.

Fifteen species of adventive plants were noted, which makes up 11% of the flora. Adventive plants appear as a result of anthropogenic impact on phytocenoses, i.e. the number of adventitious plants in the flora is affected by the intensity of the anthropogenic impact. Therefore, they can be a sensitive indicator of anthropogenic stress. Thus, alien plants take an active part in the formation of the flora of railway embankments.

Most plant species present at the studied plots belong to the meadow type of vegetation. These species are dominant in the meadow phytocenosis. By the number of species, the group of weeds is also numerous, the presence of which indicates anthropogenic impact on the natural meadows.

By the number of species, the plots were arranged in the following order: 2→1, 3→4, 5→6.

It has been demonstrated that the ecosystem located at plots 3-5 is experiencing the most severe oppression. The territory of plots 1-3 is in more favorable conditions.

The density of phytocenoses at the plots includes: the total average number of individuals per three meter test square - 523 (1), 423 (2), 598 (3), 135 (4), 301 (5), 299 (6) specimens of shoots per 1 m².

The phytomass value of site 1 (raw phytomass - 1636.90 g/m², dry - 743.06 g/m²) is five times higher than the phytomass of site 4 (raw phytomass - 341.25 g/m², dry - 169.55 g/m²) and four times higher than the indicators of the phytomass of plot 5 (raw phytomass - 456.36 g/m², dry - 169.55 g/m²) The productivity indicators by phytocenosis oxygen at site 1 (989.33 g) also significantly exceed the corresponding values for sites 4, 5, 6 (201.69; 369.25; 345.22 g).

As a result of the study, it was revealed that the plant communities of plots 4,5,6 experience an anthropogenic impact, which affects the species composition of the vegetation cover, as well as density, biological productivity and oxygen productivity (Table 1).

Table 1. Biological Productivity (g) and Density (Number of Shoots per 1 m²) of Plant Communities at the Test Sites

Plot	Biological productivity		Oxygen productivity	Density
	Fresh phytomass	Dry phytomass		
1	1636.9	743.06	989.33	523
2	956.77	421.03	502.36	423
3	1234.25	601.33	514.36	598
4	341.25	158.99	201.69	135
5	456.36	169.55	369.25	301
6	512.69	298.36	345.22	299

It is known that the chemical composition of plants reflects the elemental composition of soils. Therefore, the excessive accumulation of anthropogenic compounds by plants is due primarily to their high concentrations in soils.

The results obtained revealed the accumulation of heavy metals in plants. For analysis, the most common plant species that were found in all areas were selected: *Pimpinella saxifraga* L., *Hypericum perforatum* L., *Trifolium medium* L.

The concentration of cadmium, zinc, lead, and chromium was determined. Cd, Cr – elements of intense absorption, Zn, Pb, – medium degree of absorption. The concentration of heavy metals in the isolated plants varied in *Pimpinella saxifraga* L. with respect to Cd 1.49 (t=1.19) – 6.81 (t=2.33), Zn 3.18 (t=1.12) – 9.58 (t=2.00), Pb 3.18 (t=2.65) – 9.58 (t=3.22), Cr 3.21 (t=1.11) – 7.52(t=2.23) mg/kg.

Cumulative ability was found in *Hypericum perforatum* L. with respect to cadmium 1.81 (t=1.25) – 8.75 (t=2.69), zinc 5.18 (t=1.36) – 13.61 (t=2.33), lead 1.32 (t=1.25) – 6.17 (t=2.55), and chromium 3.69 (t=2.47) – 13.52 (t=2.01) mg/kg.

Trifolium medium L. with respect to Cd 1.89 (t=1.69) – 9.13 (t=1.58), Zn 3.18 (t=2.77) – 11.37 (t=1.98), Pb 3.31 (t=1.88) – 6.51 (t=2.22), Cr 3.31 (t=1.19) – 13.23 (t=1.88) mg/kg. The results are reliable at p<0.05 (Table 2).

Table 2. Heavy metal content in *Pimpinella saxifraga* L., *Hypericum perforatum* L., *Trifolium medium* L., mg/kg

Plot	Cd	Zn	Pb	Cr
<i>Pimpinella saxifraga</i> L.				
1	2.68±0.02	3.18±0.03*	4.18±0.03*	3.79±0.03
2	2.43±0.04	4.18±0.03	3.32±0.03	4.69±0.03
3	1.49±0.03*	4.63±0.03*	2.03±0.02*	3.21±0.02
4	5.62±0.06	9.58±0.09	4.52±0.05*	7.52±0.06*
5	2.77±0.06	8.91±0.08*	5.31±0.06*	5.52±0.04
6	6.81±0.05	7.18±0.07	8.58±0.05	6.08±0.05*
<i>Hypericum perforatum</i> L.				
1	2.59±0.02	7.62±0.07*	3.18±0.03*	4.69±0.05
2	1.81±0.03	6.05±0.07	2.67±0.02*	4.58±0.03*
3	3.80±0.05*	5.18±0.05*	1.32±0.01*	3.69±0.03
4	6.67±0.06	13.61±0.21	6.17±0.05	13.52±0.25
5	6.12±0.05	12.12±0.09	5.18±0.04*	10.58±0.11*
6	8.75±0.04*	10.05±0.09	4.67±0.05	9.58±0.09*
<i>Trifolium medium</i> L.				
1	1.89±0.01	6.18±0.05*	3.31±0.03	4.69±0.03
2	2.22±0.03	5.23±0.04	5.34±0.04	3.31±0.03*
3	3.08±0.03*	3.18±0.02	3.91±0.03	6.69±0.05*
4	9.43±0.08*	11.37±0.12*	5.58±0.05	13.23±0.23
5	7.75±0.09	9.59±0.09	4.18±0.03	10.5±0.20*
6	7.92±0.08	7.66±0.08*	6.51±0.04*	5.53±0.04*
Note: * - differences with the reference are true at P<0.05				

Thus, the plants growing at the railway track extract and concentrate various chemical elements in their organs and tissues, thereby preventing the spread of pollutants in the environment.

4 Discussion

In publications containing information on the flora near railways [1, 2, 5, 16.] the environmental factors of flora formation receive little attention. The continued active economic use of territories leads to noticeable changes in the composition and structure of plant communities [16, 17]. These changes are caused, first of all, by disturbances of the soil and vegetation cover and the emergence of new biotopes. From the point of view of preserving the landscape and biological diversity, human economic activity is negative and is known in the literature as “synanthropization of vegetation cover” [18,19].

Plants look oppressed (chlorosis, necrosis), their productivity decreases. This indicates a disturbance of the course of metabolic processes [20].

As a result of studies of the influence of railway transport, it was revealed that with the intensive functioning and operation of the railway, a lot of anthropogenic pollutants are released, including heavy metals, which are actively accumulated by the plants growing in these territories. It was noted that anthropogenic factors in the complex affect the decrease in the density of phytocenoses and biological productivity, species and quantitative composition of vegetation. The effect of anthropogenic factors manifests itself cumulatively; while one factor can activate the dynamics of the railway flora (appearance of adventive species), the other can inhibit it (reduce biodiversity).

Despite the increased interest in this problem, many issues regarding the formation of the railway flora remain unclear. The lack of a unified research methodology complicates the study of the railway phytocenoses.

To this end, we attempted to identify the main factors affecting both the formation of railroad flora and the functioning of floristic complexes.

5 Conclusion

Based on the studies conducted, it can be noted that the intense accumulation of heavy metals leads to disruption of naturally formed ecosystems, which is reflected in a decrease in species diversity, density and biological productivity. This is due to the complex environmental conditions prevailing in each of the plots. These indicators are decreasing in areas with intensive operation of railway transport. Fifteen species of adventive plants were identified, which makes up 11% of the flora. Adventive plants appear as a result of an anthropogenic impact on phytocenoses. Therefore, they can be a sensitive indicator of the anthropogenic stress. Thus, alien plants take an active part in the flora formation at railway embankments. Research in this area contributes to a deeper understanding of the processes of anthropogenic transformation of floristic complexes and should be the basis for environmental monitoring of disturbed habitats.

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