Man-made impact on green areas in buffer zones along Moscow highways

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Abstract. Turf grass in a metropolis is not only responsible for improving environmental conditions. It contributes to a comfortable visual urban environment. The state of lawn grasses investigated in the buffer zones along highways in the city of Moscow signified their unsatisfactory state, which can be attributed both to incorrect selection of turf grass blending ratios and imperfection of technological operations for lawn care. High concentrations of heavy metals were found to be present in the soil and biomass of lawn grasses, which requires activities and compliance with the regulations to ensure bioremediation of territories. The use of anti-ice reagents in winter leads to a changing acidity of the soil along the transport routes, which additionally affects the initial growth of lawn grasses in spring after snow melt. To promote sustainable ground cover in the city, it is recommended to use resistant perennial plants.

1. Introduction

Lawns have a great effect on the creation of a comfortable urban environment. These are not only well-known facts about a positive effect produced by lawns on the environmental features of the territory like lowering the temperature in the surface air layer, reducing the overall pollution and dustiness of the territory, increasing humidity and combating erosion [1, 2]. Lawns play an important role in shaping the visual urban environment. They foster a coloristic passport of the territory. These green areas help a human visual apparatus to rest in a harsh urbanized environment filled with man-made elements [3, 4]. Green is widely used in chromotherapy to relieve excessive stress and normalize human biorhythms [5]. Moreover, it is not always probable to see a sustainable herbaceous cover of the desired green color in a megalopolis. A significant variation in the color tone of a lawn is due to the state of the plants, which, in turn, directly depends on the crops (grass mixtures) used and technological methods for caring for plantings in the city. The challenge of creating and keeping grass coverings in a city is becoming more acute every year. This is facilitated by a growing rate of urbanization through an increase in soil pollution. The situation with grass coverings is particularly difficult in the buffer zones of transport highways [6]. Soil pollution is caused by both heavy metals and various ameliorants added into the soil.
2. Materials and methods

2.1. The state of herbaceous cover

The state of urban turf grasses was evaluated based on a Laptev 30-point scale. The evaluation involves assessing the productivity of shoot formation on a 6-point scale. Then it is necessary to assess the overall ornamental characteristics of turf grassy on the basis of grass stand density and projective cover on a 5-point scale.

| Herbage density (shoot formation) | Projective cover, % | Estimation, point |
|-----------------------------------|---------------------|------------------|
| Cohesive-uniform                  | 100                 | 5                |
| Cohesive-dotted                   | 70-80               | 4                |
| Mosaic-tussock                    | 50-60               | 3                |
| Tussock-bunch                     | <50                 | 2                |
| Unit-bunch                        | 15-20               | 1                |

The projective grass cover is expressed as a percentage. It is eyeballed. Looking down at the grass stand, it is determined how much of the area is covered with the grass.

| Grass density assessment using a 6-point scale | General indicators of decorative value and grass stand on a 5-point scale | Overall maximum herbage quality assurance | Quality indicator of sod matting |
|-----------------------------------------------|-------------------------------------------------------------------------|------------------------------------------|----------------------------------|
|                                               | A                         | B                                   | C=A*B                                |
| 6                                             | 5                         |                                     | 30| High quality |
| 5                                             | 5                         |                                     | 25| Excellent    |
| 5                                             | 4                         |                                     | 20| Good         |
| 4                                             | 4                         |                                     | 16| Satisfactory |
| 3                                             | 3                         |                                     | 9 | Fair          |
| 2                                             | 2                         |                                     | 4 | Poor          |

Then we evaluate the quality of lawn grass stands on a comprehensive 30-point scale.

2.2. Accumulation of heavy metals

The paper explores the ways heavy metals are accumulated in the biomass of lawn grasses as exemplified by two sites in the city of Moscow. The studies were split up into several terms, which made it possible to identify the ways heavy metals are accumulated over time. Samples were taken just outside Pirogov city hospital No. 1 (Moscow, 8Leninsky prospect, building 10).

Biomass samples were taken at each site at five points. The first sampling point was located in close proximity to a carriageway (point 1 – 0.5 m from the verge of the carriageway). The next four points are within 5 meter radius perpendicular to the carriageway (point 2 – 5.5 m from the verge of the carriageway, point 3 – 10.5, point 4 – 15.5, point 5 – 20.5 m from the verge of the carriageway, respectively).

The samples were tested at the Center for Soil-Ecological Research of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy. Heavy metals were evaluated based on measurement procedure No. 2420/692004 using an X-ray Spectroscan MAKS GV spectrometer.

2.3. The effect of anti-icing agents on the germination capacity of lawn grasses

The effect of anti-icing agents on the germination capacity of lawn grass seeds under controlled
conditions was evaluated through a series of biotests. Lawn grass seeds (perennial red darnel, red fescue) were placed in Petri dishes with solutions of Fertika IceCare Green anti-ice reagent of various concentrations (30 g/l, 15 g/l, 5 g/l, 1 g/l) and a control variant (water). After 7 days of exposure to scattered light, a number of germinated seeds was counted.

3. Results and discussion

3.1. State of urban turf grass

There are different types of turf coverings – decorative, sports, protective (special). In urban conditions, ordinary (garden and park) turf grasses are usually created, which fall within decorative. To develop special techniques for lawn care, it is necessary to assess its condition [7]. Having evaluated the condition of several sod mattings across Moscow, the authors obtained the following results. On average, a number of shoots on an ordinary allotment is 8,750 pcs/m² (Fig. 1).

![Figure 1](image)

Figure 1. Number of shoots per 1 m² on various test sites in Moscow, pcs.

An ordinary lawn is characterized by a mosaic-tussock pattern. The general decorative value of an ordinary grass stand is 3–4 points. Ordinary sod mattings along roads and highways were found to be in a particularly depressing state, as evidenced by the results of a comprehensive decorativeness assessment. An ordinary lawn scored only 15.2 points – the quality is satisfactory.

Thus, the state of urban turf grasses, especially nearby city throughways, is not optimal. In this state, these lawns are not able to completely fulfill their sanitary and hygienic function and fail to ensure the creation of a comfortable visual urban environment.

3.2. Heavy metal content

The growth of lawn grasses depends on a number of factors. These include climatic factors (falling within abiotic factors) and man-made factors. Harsh disturbances in the growth and development of plants in large cities is caused by soil pollution. One of the main soil pollutants in the city is the traffic – a source of heavy metals and oil pollution [8]. The research object is located near Leninsky Prospekt, one of the busiest transport routes in the capital.

Over time (May, September), the content of heavy metals was investigated in soils and in lawn grasses, growing in close proximity to the roadway and at a certain distance away.

The findings suggest that the content of heavy metals varied significantly depending on the location of a sampling point and study dates (Table 3).

In May, the highest content of heavy metals was detected at point 1, located nearby the highway. The pattern was observed for almost all heavy metals. The content of cobalt, arsenic and nickel was more evenly distributed. There were no differences found in the amount of these elements subject to the distance from the roadway.
The amount of heavy metals in the plant at the beginning of the growing season was thought to depend on the amount of heavy metals in the soil (Table 4). There was a high correlation in the content of zinc and lead in soil and plants.

The amount of heavy metals in the soil did not exceed the level of maximum permissible concentrations for all elements, except for the amount of chromium, zinc and lead. For these elements, the excess of MPC was from 5 to 300% and higher. The content of heavy metals in the soil varied according to the sampling locations. Excessive accumulation of chromium and lead was found to be present at a distance of more than 15 m from the roadway. This may be due to the urban planning situation at the sampling site (the presence of a wind corridor between buildings) and, as a consequence, the removal of heavy metals at a considerable distance from the roadbed.

### Table 3. Total heavy metals in lawn grasses, mg/kg (May)

| HM | Samples and sampling locations |
|----|--------------------------------|
|    | sampling location No. 1 | sampling location No. 2 | sampling location No. 3 | sampling location No. 4 | sampling location No. 5 |
| Cr | 35.8±1.79               | 28.3±1.42               | 28.0±1.40               | 28.9±1.45               | 27.3±1.37               |
| MnO| 118.9±8.94              | 138.1±6.90              | 95.1±4.76               | 99.3±4.97               | 100.6±5.03              |
| Co | 11.0±0.55               | 9.5±0.48                | 9.8±0.49                | 8.9±0.44                | 9.4±0.47                |
| Ni | 50.3±2.52               | 46.5±2.32               | 46.8±2.34               | 48.9±2.44               | 49.7±2.48               |
| Cu | 36.6±1.83               | 21.0±1.05               | 32.0±1.60               | 26.1±1.32               | 23.3±1.17               |
| Zn | 132.1±6.60              | 89.2±4.46               | 130.0±6.50              | 135.9±6.80              | 125.9±6.29              |
| As | 96.1±4.81               | 81.9±4.10               | 78.5±3.92               | 83.7±4.19               | 76.0±3.80               |
| Pb | 102.1±5.11              | 88.0±4.40               | 95.0±4.75               | 89.0±4.45               | 78.3±3.92               |

### Table 4. Total heavy metals in soil, mg/kg (May)

| HM  | Samples and sampling locations | MPC level, mg/kg |
|-----|--------------------------------|------------------|
|     | sampling location No. 1 | sampling location No. 2 | sampling location No. 3 | sampling location No. 4 | sampling location No. 5 |      |
| Cr  | 84.6±4.23               | 87.5±4.37               | 95.8±4.79               | 213.9±10.70              | 160.7±8.04               | < 90 |
| MnO | 640.6±32.03             | 883.2±44.16             | 902.4±45.12             | 913.5±45.67              | 1046.2±52.31             | < 1500 |
| Co  | 13.4±0.67               | 9.2±0.46                | 15.0±0.75               | 12.9±0.49                | 12.9±0.65                | < 20 |
| Ni  | 45.4±2.27               | 47.6±2.38               | 71.6±3.58               | 80.0±4                   | 70.9±3.55                | < 80 |
| Cu  | 45.8±2.29               | 40.7±2.03               | 46.3±2.31               | 91.2±4.56                | 69.5±3.48                | < 130 |
| Zn  | 324.5±16.23             | 254.9±12.75             | 745.3±37.27             | 734.2±36.71              | 672.9±33.64              | < 220 |
| Pb  | 150.2±7.51              | 198.1±9.90              | 188.8±9.44              | 231.9±11.59              | 219.5±10.97              | < 120 |

At the end of the vegetation season, the amount of heavy metals in plants, generally, went up from several percent to 30-40% compared with the primary data (Table 5). The content of nickel and arsenic remained almost unchanged.

The concentration of heavy metals in the soil increased at the end of the season (Table 6), with the highest amount to be found at a distance of up to 15 meters from the roadway. The increase was up to 60% relative to the content of heavy metal in the soil in May and was especially strong for metals such as cobalt, copper, zinc and lead. The excess of the MPC level for such elements as chromium, zinc and lead was also noticeable. At a distance of more than 15 meters, the soil was partially cleared, likely...
due to the absorption of excess metals by lawn grasses (perennial red darnel), their accumulation in the biomass and removal from the area during planned mowing.

Thus, we see an excess content of heavy metals in soils near busy transport routes. Being freed from pollution is partially facilitated by a phytoremediation function of turf grasses – the ability to absorb and accumulate heavy metals in biomass. In this regard, green care activities should involve utilization of mowed grass along with contaminated soil at special landfills. This technological operation implies a high cost of disposal. In urban conditions it makes sense to pay attention to the use of not only traditional turf grasses, but also of other plants that provide the formation of stable grass stands [9].

### Table 5. Total heavy metals in lawn grasses, mg/kg (September)

| HM | sampling location No. 1 | sampling location No. 2 | sampling location No. 3 | sampling location No. 4 | sampling location No. 5 |
|----|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Cr | 30.9±1.55               | 34.0±1.70               | 31.4±1.57               | 29.0±1.45               | 26.8±1.34               |
| MnO| 99.2±4.96               | 117.1±5.86              | 87.8±4.39               | 109.1±5.46              | 114.2±5.71              |
| Co | 11.1±0.56               | 11.0±0.55               | 11.1±0.56               | 10.6±0.53               | 10.6±0.53               |
| Ni | 47.7±2.38               | 46.6±2.33               | 46.9±2.34               | 48.6±2.43               | 47.7±2.38               |
| Cu | 30.1±1.50               | 25.0±1.25               | 37.4±1.37               | 38.5±1.92               | 24.1±1.21               |
| Zn | 104.1±5.20              | 108.1±5.41              | 106.3±5.32              | 169.9±8.50              | 62.3±3.12               |
| As | 26.6±1.33               | 27.1±1.36               | 26.9±1.34               | 25.7±1.28               | 22.6±1.13               |
| Sr | 90.7±4.54               | 97.8±4.89               | 88.0±4.40               | 90.9±4.55               | 91.3±4.57               |
| Pb | 102.3±5.12              | 101.8±5.09              | 102.3±5.11              | 95.0±4.75               | 103.9±5.20              |

### Table 6. Total heavy metals in soil, mg/kg (September)

| HM | sampling location No. 1 | sampling location No. 2 | sampling location No. 3 | sampling location No. 4 | sampling location No. 5 | MPC level |
|----|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|------------|
| Cr | 100.7±5.04              | 120.4±6.02              | 119.9±5.99              | 152.6±7.63              | 155.7±7.78              | < 90       |
| MnO| 719.0±35.95             | 1105.7±55.28            | 1056.4±52.82            | 809.1±40.45             | 861.4±43.07             | < 1500     |
| Co | 16.1±0.81               | 8.7±0.43                | 20.0±1.00               | 20.4±1.02               | 6.8±0.34                | < 20       |
| Ni | 61.4±3.07               | 56.6±2.83               | 67.4±3.37               | 64.4±3.22               | 68.5±3.43               | < 80       |
| Cu | 68.9±3.44               | 49.6±2.48               | 53.6±2.68               | 65.7±3.29               | 66.1±3.30               | < 130      |
| Zn | 396.5±19.83             | 344.0±17.20             | 549.4±27.47             | 572.3±28.62             | 622.3±31.12             | < 220      |
| Pb | 201.6±10.08             | 206.1±10.30             | 219.9±11.00             | 235.0±11.75             | 245.4±12.27             | < 120      |

### 3.3. Response of lawn grasses to soil salinity

Besides excessive heavy metals in the buffer zones along Moscow linear transport routes, as shown above, anti-ice reagents have a negative effect on green spaces. The largely uncontrolled introduction of anti-ice reagents onto the roadway during the winter season brings about changing soil acidity, which have a negative impact on seed germination of lawn grasses in spring and plant growth at large. This requires the current roadside lawn care guidelines to be recalibrated [10].

The results of a series of biotests clearly demonstrate the dependence of seed germination of lawn grasses on the concentration of anti-ice reagent (Table 7).

Red darnel can be considered the most resistant lawn grass to a high level of anti-ice reagent. However, the widespread introduction of lawn mixtures with a predominance of red darnel is hampered by its low winter hardiness in the conditions of central Russia.
Table 7. Germination of turfgrass seeds in pollutant solutions, %

| Turf grass          | Pollutant concentration, g/l |
|---------------------|-----------------------------|
|                     | control (water) 1 5 15 30   |
| Red darnel \( L. \) | 100 95 93 95 0             |
| Red fescue \( L. \) | 85 85 70 35 0              |

4. Conclusion
The studies have shown that arranging lawn grass stands in the harsh urbanized environment of a metropolis is especially acute today. The deteriorated quality of sod matings is caused not only by inadequate care lawn, but also by the lack of resistance of traditional lawn grasses to a complex of unfavorable soil factors. The most important factors include the excessive accumulation of heavy metals in the soil and a change in its acidity due to the introduction of unregulated doses of anti-ice reagents in winter.

It is necessary to clarify at the legislative level the technical regulations for lawn care activities: the removal and disposal of cut grass as a particularly contaminated biomass. A current sod-humus system of lawn care leads to re-contamination of the soil with heavy metals previously absorbed by lawn grasses.

It is necessary to organize sod matings in a megalopolis – sustainable ground cover – from perennial plants with high accumulation rates of heavy metals and resistant to changes in soil acidity throughout the year. A one-time mowing of these plants at the end of the season and disposal of plant residues will result in a gradual biological purification (reclamation) of soils in the metropolis.

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