Assessment of sanitary parameters of soils in cedar stands

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Abstract. The article presents the results of a study of the sanitary-microbiological parameters of soils in cedar stands on the example of the Vologda Oblast of Russia. The taxation description of cedar plantations showed that both urban and Siberian cedar plantings in the urban environment and beyond are distinguished by good growth. In the studied objects, the presence of phytopathogenic fungi dangerous for trees was found in soils, such as Aphanomyces, Fusarium, Phytophthora, Pythium, Verticillium, and the presence of saprotrophic fungi with antagonistic properties, such as Mucorales, Clonostachys, Trichoderma, Mortierella, Mucor. Phytopathogenic activity correlates inversely with the activity of saprotrophs-antagonists found in the zone of coexistence. According to microbiological indicators, the diversity of antagonistic fungi with signs of high suppression indicates the well-being of the studied soil samples. Based on the sanitary-microbiological assessment in the studied cedar groves, recommendations were developed and proposed for protecting soils in the cedar stands, such as selective forest protection measures, clearing of litter, and laboratory tests to determine the toxicity of soils that affect the growth and development of cedar stands.

1 Introduction

The urban environment is a system of natural, natural-anthropogenic (technogenic) and socio-economic conditions that can have a significant impact on residents of cities whose habitats are [1-3]. Indicators of the quality of the urban environment are indicators of sustainable development of the city, the creation of an environmentally friendly urbanized environment – an actual direction of our time [4-6]. It is especially relevant to apply with the development of solar energy and other alternative energy sources [7-22]. These technologies, combined with rapid control methods for environmental control, give high results in creating an environmentally...

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This work is aimed at studying the soil conditions of the Chagrinsky and Gryazovetsk cedar groves and a nursery near the village of Zhernokovo. This study makes an essential contribution to improving the environmental situation of the Gryazovetsk district of the Vologda region.

Cedar forests in the studied objects have important recreational, sanitary-hygienic, and reproductive values. For the growth of healthy cedar plantations, it is necessary to take into account many factors during the growing process, one of the most important is the soil cover, namely, its microflora, microbiological parameters, and the content of toxic elements associated with the rhizospheric part of cedar pine.

The purpose of the study is to study the microbiological, toxic parameters, and microbial population of the soil in the cedar stands of the Vologda Oblast.

2 Materials and research methods

The objects of research are cedar groves and a nursery in the Gryazovets district of the Vologda region, namely the Chagrinsky cedar grove, Gryazovets cedar groves and a cedar nursery near the village of Zhernokovo.

Siberian cedar pine grows in the cedar groves of the Gryazovets region, which is a valuable nut-bearing species that has adapted to the climatic conditions of the region. Cedar plantations have cultural, historical, recreational, and aesthetic values. Microbiological studies are aimed at detecting and quantifying microorganisms, assessing the level of enzymatic activity, analysis for the content of heavy metals in the soil of cedar groves and nursery. These studies are relevant modern areas of work with forest areas, which are necessary to maintain the sanitary and hygienic characteristics of plantations, preserve valuable tree species, model, and develop environmental measures [2, 5].

The first investigated object – the Chagrinsky cedar grove, is a natural botanical monument of regional significance from 01.29.1963. The Chagrinsky cedar grove is located in the Vologda Oblast, Gryazovets Municipal District (Chagrino Village), the area of which is 3.7 hectares.

The Chagrinsky grove is located at the junction of the Vologda Upland and the Prisukhonskaya Lowland, which has the shape of an elongated quadrangle, located 36 km from the city of Vologda and 23 km from the city of Gryazovets. The founder of the Chagrinsky grove was the landowner N.A. Petrov, who in 1900-1901, near the village of Shipyakovo, supervised the planting of oak, holly maple, small-leaved linden, ash, and hazel, as well as ordinary pine and cedar pine. The Chagrinsky grove was laid by five to ten-year-old cedar trees, and wild animals landed at a distance of ten by ten meters. To date, the park has 28 rows of old plantings, each of which has preserved from 4 to 22 trees up to 12 meters high. The most potent trees with a diameter of 60 to 80 cm are located in the middle of the plantings located on a low hill. In the early 90s, young pine trees at age 15 to 20, small-leaved linden, and spruce were planted. Currently, 133 cedars with mighty trunks are preserved in the grove, the average height of which is 19.5 m.

The second subject of research was the Gryazovets cedar grove, which was laid in 1966. Gryazovets cedar grove is located 47 km from the city of Vologda. The area of the grove is one hectare. About 300 six-year-old cedar seedlings were planted in the grove, grown first in greenhouse conditions, and then in open ground. Previously, the area was plowed, cultivated, drilled.
Plants were planted at a distance of four by four meters. For each seedling, a seat was prepared with the introduction of rotted manure, composts mixed with sand, and mineral fertilizers. Along the perimeter, the territory was delineated.

In the early years, trees were carried out by agrotechnical students of the local technical school. The date of this plantation creation is memorialized in the memorial sign in the center of the grove. Currently, the plantation is represented by 78 cedars of different living conditions with an average trunk diameter of 20 to 30 cm.

The third research object was the cedar nursery near the village of Zhernokovo, which is 71 km from the city of Vologda and 23 km from the city of Gryazovets. Planting was established in 1977 by planting seedlings of four to five years old, which were originally grown from seeds and harvested in the Chagrinisky grove. The landing area is 1.2 hectares. Today, about 500 cedars grow in the nursery. In the nursery, there is a commemorative sign with the date of creation of this plantation.

When presenting the material, forest taxation methods were used. In the course of the study, a taxation characterization of cedar plantations in the studied objects was made according to indicators describing qualitative and quantitative characteristics: age, number of trees in the grove, average trunk height, average trunk diameter, and average crown diameter.

Assessment of the sanitary condition of trees in cedar groves and the nursery plantings was distributed according to the sanitary status classes according to several signs: loss of needles, loss of green color of needles, top condition, condition of a tree trunk [35-37].

Soil samples were taken using a scoop in the near-tree circle of trees from 5 points around the trunk; soil was taken from a depth of 10-20 cm from each section of groves. A top layer of 3 cm thick was removed to prevent extraneous microflora from entering.

The prevalence (frequency of occurrence) of soil fungi was taken into account by the method of sowing soil particles (1-1.5 mm) in Petri dishes on Chapek's agar from diluting the soil suspension – CFU x105 in gr. soil and the method of sowing micro lumps of soil – the frequency of occurrence to the number of sown lumps in%. The repetition of crops of each sample = 7. Growing fungi were identified by microscopy according to morphological characteristics [3, 6, 38].

3 Results and discussion

The taxation description of cedar stands in the research objects was carried out in the areas of Chagrinisky, Gryazovets, and Zhernokovo settlements. The taxation description includes indicators that describe the qualitative and quantitative characteristics: age, number of trees in the grove, average trunk height, average trunk diameter, average crown diameter.

Both park plantings of Siberian cedar and in the vicinity of settlements in the studied objects are characterized by good growth. Good coverage of crowns, achieved by a rare landing, contributed to their development and increased trunk growth in diameter.

To date, 133 cedars with mighty trunks, the average height of which is 19.5 m, have survived on 3.7 hectares of the Chagrinisky grove. In Gryazovetsk Grove, whose area reaches one hectare, 78 cedars with an average trunk height of 12.4 m. The nursery near the Zhernokovo village has an area of 1.2 hectares and about 500 cedars with an average height of 12.3 m grow in it. So, by the 117-year-old age of the Chagrinisky grove, the average trunk diameter is 62.1 cm, and the average crown width is 6.9 m. Both in the Gryazovets grove and the nursery, the average trunk diameter is 25.1 cm, an indicator of the average crown width in the first object – 3.7 m, in the second – 4.1 m.

When distributing trees according to the sanitary condition classes, the most significant parts
are assigned to the second class (43%, 49%, and 47%). Wood plantings of I, II, and III class of sanitary conditions are quite viable. The difference between shrinking and fresh dead wood is that the probability of their death is not determined; it is likely random soon than expected and natural. There is no reason to expect the drying of trees of these categories soon.

During the chemical analysis, the acidity of the soils was also determined; the pH values are 4.98 (Gryazovets), 4.61 (Chagrino), and 4.68 (Zhernokovo), the medium is slightly acidic and corresponds to podzolic and sod-podzolic soils. The value of acidity is suitable for the growth of conifers, the vital activity of microorganisms, and the course of various biochemical processes.

Numerous populations of various microorganisms inhabiting the soil cover differing in ecological functions and taxonomic position are generalized by the concept of “soil biota.” Among microorganisms, bacteria, actinomycetes, microscopic fungi, and living creatures close to these groups are observed.

Fluctuations in the number of soil microorganisms (an indicator of soil biogenicity) are observed not only during the year, but also over relatively short periods, and the effect is the temperature, humidity, phase of plant development, and organic debris entering the soil. Soil microflora is under the direct and powerful influence of leaf litter, which acts as the primary source of nutrients and microflora washed into the soil.

The generally accepted method of microbiological analysis of the soil was used to identify, study and account for the number of soil fungi of the phytopathogenic complex, their antagonists that dominate the microflora complex of cedar groves (Gryazovets, Chagrino) and the nursery (village Zhernokovo).

Morphological microscopy was used to identify growing fungi. The results of the analysis of soil samples for the presence of phytopathogenic fungi are presented in the tables (Table 1, Table 2, Table 3, Table 4).

Table 1 Phytopathogenic fungi that dominate the microflora complex of cedar groves and nursery (May 2017)

| Types of mushrooms | Occurrence, % of the number of samples of basal soil from the territory of cedar stands |
|--------------------|------------------------------------------|
|                    | Zhernoko | Chagrino | Gryazovets |
| Aphanomyces sp.     | 15       | 20       | 15         |
| Fusarium semitectum | 7        | 9        | 7          |
| Fusarium oxysporum  | 5        | 15       | 4          |
| Peinicilium albicans| 1        | 2        | 3          |
| Peinicilium lilacinum| 2       | 1        | 1          |
| Peinicilium sp.     | 1        | 0        | 0          |
| Pythium aphanidermatum| 10    | 15       | 20         |
| Pythium acanthophoron| 20    | 17       | 12         |
| Phytophthora capsici| 1        | 0        | 0          |
| Rhizopus stolonifer (Edson) | 2 | 10       | 0          |
| Rhizopus sp.        | 1        | 0        | 1          |
| Verticillium albo-atrum| 4    | 5        | 2          |
| Verticillium chlamydosporium| 1 | 0,5      | 1          |
| Verticillium capitatum| Her. | 0        | 3          |
In 2017, soil samples were selected on the territories of cedar stands. It was established that the occurrence of phytopathogenic fungi in the samples is in close values from each other. The maximum occurrence of phytopathogenic fungi occurs in fungi of the species *Pythium acanthophoron*, which is 12% (Gryazovets), 17% (Chagrino) and 20% (Zhernokovo) of the number of root-soil samples from the territory of cedar stands, as well as *Aphanomyces* species, the occurrence of which is from 15% (Gryazovets and Zhernokovo) and up to 20% (Chagrino), *Pythium aphanidermatum* – 10% (Zhernokovo), 15% (Chagrino) and 20% (Gryazovets) of the number of root-soil samples from the territory of cedar stands.

Table 2 Phytopathogenic fungi that dominate the microflora complex of cedar groves and nursery (September 2017)

| Types of mushrooms                  | Occurrence,% of the number of samples of basal soil from the territory of cedar stands |
|-------------------------------------|----------------------------------------------------------------------------------------|
|                                     | Zhernokovo | Chagrino | Gryazovets |
| Альтернария (*Alternaria longipes* (Ellis & Everh.) E.W. Mason) | 3          | 6        | 1          |
| Aphanomyces sp.                     | 2          | 5        | 0          |
| *Fusarium semitectum* Berk. et Rav. | 10         | 12       | 9          |
| *Fusarium oxysporum* Schlecht       | 12         | 15       | 15         |
| *Penicillium albicans* Bain.        | 3          | 2        | 5          |
| *Penicillium lilacinum* Thom        | 5          | 3        | 1          |
| *Penicillium sp.*                   | 2          | 1        | 1          |
| *Pythium aphanidermatum* (Edson) Fitz. | 1.5       | 0        | 1          |
| *Pythium acanthophoron* Sideris     | 1          | 0        | 4          |
| *Phytophthora capsici* Leonian      | 2          | 2        | 0          |
| *Rhizopus stolonifer* (Ehrenb.) Vuill. | 2          | 1        | 0          |
| *Rhizopus sp.*                      | 3          | 2        | 2          |
| *Verticillium albo-atrum* Reinke et Berth. | 20         | 15       | 12         |
| *Verticillium chlamydosporium* Goddard | 2          | 1        | 0          |
| *Verticillium capitatum* Her.       | 1          | 1        | 5          |

It is typical for soil samples taken in cedar plantations in 2017 that the occurrence of phytopathogenic fungi is close to each other. The maximum occurrence of phytopathogenic fungi occurs in fungi of the species *Verticillium albo-atrum*, which is 12% (Gryazovets), 15% (Chagrino), and 20% (Zhernokovo) of the number of root-soil samples from the territory of cedar stands. The occurrence of the species of fungi *Fusarium oxysporum* ranges from 12% (Zhernokovo) and up to 15% (Gryazovets and Chagrino) of the number of root-soil samples from the territory of cedar stands. The occurrence of the species of *Fusarium semitectum* mushrooms is somewhat lower. Occurrence values for the remaining species are less than six percent. In 2018, soil samples were analyzed for the presence of saprotrophs and antagonists of phytopathogenic fungi (Table 3). Among the microflora of cedar groves and nursery that prevail in the complex, the highest values of the occurrence of saprotrophs and antagonists are observed in fungi of the species *Mucor racemosus* and *Trichoderma koningii*. The occurrence of fungi of the species *Mucor racemosus* is 9% (Gryazovets), 10% (Zhernokovo), and 15% (Chagrino) of the number of root-soil samples from the territory of groves. The occurrence of fungi of the species *Trichoderma koningii* is from 10% (Gryazovets) to 25% (Zhernokovo and Chagrino) of the number of root-soil samples from
the territory of cedar stands. The occurrence values for other types of saprotrophs and antagonists that dominate the microflora complex of cedar groves and nursery are shown in the Table (Table 3).

Table 3 Types of saprotrophs and antagonists that dominate the microflora complex of cedar groves and nursery (May 2018)

| Types of mushrooms                  | Occurrence,% of the number of samples of basal soil from the territory of cedar stands |
|-------------------------------------|----------------------------------------------------------------------------------------|
|                                     | Zhernokovo | Chagrino | Gryazovets |
| Mortierella alpina Peyronel         | 1          | 3        | 5          |
| Mortierella elongata Linnemann      | 1          | 2        | 0          |
| Mortierella sp.                     | 2          | 0        | 3          |
| Mucor racemosus Fres                | 10         | 15       | 9          |
| Mucor sinensis Milko                | 10         | 0        | 0          |
| Mucor sp.                           | 3          | 2        | 3          |
| Trichoderma album Preuss            | 0          | 23       | 15         |
| Trichoderma koningii Oud            | 25         | 25       | 10         |
| Clonostachys sp.                    | 8          | 7        | 8          |

In 2019, soil samples were selected, the analysis of which shows that the highest values of the occurrence of saprotrophs and antagonists were observed in fungi of the species Mucor elongata and Trichoderma koningii. The occurrence of the species of fungi Mucor elongata is 7% (Chagrino), 10% (Zhernokovo), and 15% (Gryazovets) of the number of root-soil samples from the territories of cedar stands. The occurrence of the species Trichoderma koningii mushrooms is from 17% (Gryazovets and Zhernokovo) to 27% (Chagrino) of the number of root-soil samples from the territories of cedar stands. Occurrence values for the remaining species are shown in the Table (Table 4).

Table 4 Types of saprotrophs and antagonists that dominate the microflora complex of cedar groves and nursery (September 2019)

| Types of mushrooms                  | Occurrence,% of the number of samples of basal soil from the territory of cedar stands |
|-------------------------------------|----------------------------------------------------------------------------------------|
|                                     | Zhernokovo | Chagrino | Gryazovets |
| Mortierella alpina Peyronel         | 6          | 1        | 10         |
| Mortierella elongata Linnemann      | 10         | 7        | 15         |
| Mortierella sp.                     | 0          | 7        | 3          |
| Mucor racemosus Fres                | 4          | 3        | 3          |
| Mucor sinensis Milko                | 5          | 1        | 1          |
| Mucor sp.                           | 0          | 0        | 0          |
| Trichoderma album Preuss            | 3          | 12       | 15         |
| Trichoderma koningii Oud            | 17         | 27       | 17         |
| Clonostachys sp.                    | 8          | 7        | 8          |

The presence of phytopathogenic fungi and their natural antagonists was established in soil samples. Phytopathogenic fungi dangerous for trees include fungi of the genus Aphanomyces, Fusarium, Pythium, Verticillium, and less commonly others. However, in nature, their potential harmfulness is not always manifested, even if they appear in the dominant group of mycocenosis species that develop on plant litter. The phytopathogenic
activity of fungi correlates inversely with the activity of saprotrophs, which are their antagonists, found in the zone of coexistence.

Numerous species of saprotrophic *Trichoderma* and fungi of the order *Mucorales* dominate in soil samples, which can exhibit hyperparasitic activity against phytopathogenic species.

Under the canopy of trees, together with a complex of soil fungi (saprotrophs and parasites), antagonist species from the genus *Clonostachys, Trichoderma, Mortierella, Mucor* were identified. A variety of species of saprotrophic fungi with antagonistic properties indicates the well-being of the soil according to microbiological indicators with signs of high suppression, that is, the ability to suppress phytopathogenic activity.

4 Conclusions

The studied cedar groves and the nursery are subject to recreational loads: rest of tourists, collecting cedar cones, needles. As the taxation description of the plantations showed, cedar plantings successfully continue their growth and bear fruit. When trees are distributed according to the sanitary condition classes, the most substantial parts are assigned to the second class, which indicates a weakening of the stands with their satisfactory viability. There is no reason to expect the trees to dry out any time soon.

The soil cover is one of the leading deposition media in which the accumulation of heavy metals arriving with precipitation, leaf fall, dead parts of plants. The danger of these elements is manifested in the fact that they can accumulate in the cells of living organisms, to be included in ecological chains, to form highly toxic compounds, without being biodegradable.

According to taxation indicators (quantitative and qualitative characteristics of cedar stands), it was found that both urban and park plantings of Siberian cedar in Gryazovets and outside the urban environment: in the village of Chagrino and near the village of Zhernkovo, are characterized by good growth. Good coverage of crowns, achieved by a rare landing, contributed to their development and increased trunk growth in diameter.

According to the results of the sanitary assessment, the most substantial part of the cedar stands (43%, 49%, and 47%) in the studied objects is assigned to the second class (weakened). The tree plantings of the second class of state are quite viable; the probability of their death has not been determined; there is no reason to expect the trees to dry out soon.

In a comprehensive assessment of the urban environment state, much attention is paid to the microbiological study of the soil cover of cities. Constant pressure is exerted on the soil by transport, industry, and the construction industry, which leads to a change in almost all of its components, from agrochemical, physical properties to microbiological and biochemical parameters, depriving the urban soil cover of the ability to perform critical environmental functions. “Soil biota” is a generalized concept for designating the populations of soil cover of numerous populations of various microorganisms that differ in ecological functions and taxonomic position.

In the studied objects, the presence of phytopathogenic fungi dangerous for trees in soils was found: *Aphanomyces, Fusarium, Phytophthora, Pythium, Verticillium*, and saprotrophic fungi species with antagonistic properties: *Mucorales, Clonostachys, Trichoderma, Mortierella, Mucor*. Phytopathogenic activity correlates inversely with the activity of saprotrophs, which are their antagonists found in the zone of coexistence. According to
microbiological indicators, the diversity of antagonistic fungi with signs of high suppression indicates the well-being of the studied soil samples.

Based on the previous, it can be noted that indicators of the quality of the urban environment are indicators of sustainable development of the city. The creation of an environmentally friendly urbanized environment is a relevant trend of our time. In this work, indicators of the environmental aspects of sustainable development are the conservation of soil cover, land quality, rational use, maintenance and conservation of natural ecosystems, vegetation cover, namely, the studied pine stands.

Actual environmental measures to achieve the sustainable development and functioning of the Chagrinlinskaya, Gryazovetskaya cedar groves and nursery near the village of Zhernokovo: assessment of the sanitary condition of the forest stand with the aim of timely detection of weakened individuals, selective sanitary felling, cleaning of litter, as well as laboratory studies to identify phytopathogenic soil microorganisms, by definition soil toxicity, affecting the growth and development of cedar stands.

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