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# Environmental Diagnostics of Anthropogenic Transformation for Specially Protected Areas

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**Abstarct:** The testing of comprehensive diagnosis procedure for ecosystem anthropogenic is performed. As an object of study two well protected areas were selected. These are the territories with a marked contrast level of anthropogenic impact. Geochemical, physiological and landscape-indicative values of pine ecosystems were investigated as the part of this study. The study results revealed the indicators of anthropogenic transformation in specially protected areas. A series of environmental measures was developed to optimize the state of the environment.

**Key words:** Bioindication · Environmental Geochemistry · Landscape Display · Anthropogenic Transformation · Protected Areas

## INTRODUCTION

Currently, the degradation of forest ecosystems under the influence of various kinds of anthropogenic factors is the actual problem, which is particularly acute in urban areas where the natural environment experiences an increased complex exposure. The loss of a forest ability to perform its ecological functions is reasoned by a significant and continiously increasing anthropogenic pressure on forests.

Specially protected nature areas (SPNA) are established to prevent environmental degradation. They become the areas of past natural balance restoration or hinder the progress of adverse changes. SPNA state requires systematic observations [1].

Nowadays, there are many methods of anthropogenic transformation indication concerning the environment, but most of them can not identify violations in ecosystem at an early stage of its ecological status change [2]. The information about the effects of chemical elements concentrations in ecosystem on biological objects is particularly important. The reaction of woody plants to anthropogenic influence depends on many environmental factors [3]. The diagnostics of ecosystem transformation can be performed by the comparison of similar ecosystems under the influence of various anthropogenic load [4].

Among forest tree species one of the most common indicators is Scots pine (*Pinus sylvestris* L.) [5]. Scots pine is highly sensitive to high concentrations of toxic substances in the environment.

## MATERIAL AND METHODS

The studies were conducted on specially protected natural territories "Chernyayevsky forest" and "Osinskaya forest cottage". The protected natural landscape of local importance "Chernyayevsky Forest" (with the area of 685.97 ha) is a woodland, which is located almost in the center of Perm city, surrounded by residential areas. The protected landscape of regional significance "Osinskaya forest cottage" (with the area of 12,168 ha) located nearly 100 km southwest of the city of Perm is accepted as a background territory. The studies were carried out according to the "Complex diagnostics of anthropogenic transformation for specially protected areas" [6], developed at the University of Perm city. The following types activities were carried out during the

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study: the determination of ecosystem degradation; geobotanic descriptions of vegetation; forest mensuration parameters; physiological state of vegetation of Scots pine needles according to chlorophyll fluorescence with the use of "Photon-10" fluorometer [7], geochemical parameters of soil and Scots pine needles. Landscape indication was performed on the basis of remote sensing data analysis with the use of ENVI 4.7 and ArcGIS 9.3 software. The GIS databases were developed for the study areas, including the research results in its structure.

The pine types of forest of green moss group were preliminary provided for SPNA to perform indicative studies that were specified in the field conditions. 30 sample plots were founded in both territories. 600 samples of pine needles were selected to measure the delayed fluorescence of chlorophyll, 60 samples of soil and pine needles for geochemical analysis.

## RESULTS AND DISCUSSION

Chlorophyll fluorescence is directly affected by abiotic factors of the environment. So the schedules of the average daily change in the relative rate of delayed fluorescence (RRDF) were drafted for explored territories depending on temperature and air humidity (Fig. 1).

During daytime photosynthetic depression in hot and dry weather RRDF is reduced to 2 on the model plot at Chernyayevsky forest and to 4 at Osinskaya forest cottage. The most diferences are observed in the morning and evening periods. Significant differences are observed in the period from 10:00 a.m. to 15 p.m. at low temperatures and high humidity.

The daily change of chlorophyll fluorescence at the model site of Osinskaya forest cottage Osinskaya is taken as a background when photosynthetic activity of Scots pine assimilatory organs is estimated on test plots of both SPNA (Table 1).

On the average, SPNA value at Osinskaya forest cottage sites is 8% (± 4%) less from the background. On the average, SPNA value at Chernyayevsky forest sites is 25% (± 3 %) less from the background.

SPNA value under the significant anthropogenic load is 25% or more less relative to the background. This deviation of value indicates on anthropogenic impact, even at the early stage of ecosystem degradation. Thus, under the anthropogenic impact is significantly reduced the delayed fluorescence of Scots pine chlorophyll assimilation is significantly reduced.

According to the results of geochemical analysis common geochemical features of the studied areas are identified (Fig. 2, 3). The content of Zn, Cu, P, Co in the soil exceeds world soil clarke almost 2 times. Ni content within the clarke is also uncommon for light-textured soils. Relatively low accumulation is observed for the series of elements (Ti, Cr, Sc, Zr, Ba, Ga, Sr, Y, Sn). The clarke value of pine needles exceeds the concentration of Ga and Mn. The low accumulation of the following elements is observed: V, Cr, Ba, Ti, Pb, Co, Zn, Cu.

According to the results of geochemical studies the differences of soil and pine needle quality of Chernyayevsky forest and Osinskaya forest cottage are revealed. The light textured soils of Chernyayevsky forest have an excess of some microelements. The greatest differences are detected for Pb, Ag, Zr, Ba, Sn, Sc, Ti, Cr, Zn.

The needles of Scots pine at Chernyayevsky forest of relatively background territory have a significant accumulation of Ti, V, Cr, Cu, Ni, Co, Zr, Ga.

According to the calculation results of Chernyayevsky forest soil contamination total index 2 test areas are marked by a dangerous pollution degree, 8 test areas are marked by a moderately hazardous pollution level (Fig. 4).

The soil pollution level at all sampling sites in Osinskaya forest cottage is permissible one.

Besides an absolute accumulation (AAV), relative accumulation (RAV) values and also biological absorption coefficient are calculated to characterize the geochemical features of the territory peculiarities.

Chernyayevsky forest soils as compared with background territory have the highest accumulation rate of such elements as Ti (650 t/km$^2$), Mn (115 t/km$^2$), Cr (18 t/km$^2$), Zn (17 t/km$^2$). However, Pb and Ag accumulation is more significant (Table 2) taking into account the background content.

The result of biological accumulation row analysis shows that Scots pine needles in both areas are strongly absorbed by Mn, P, Ag, Ba, Cu, Sr, Zn, Ni. The remaining elements are only captured as incoming elements are fixed and can be retained in soils, which prevents the transition to a plant. Also, the contents of heavy metals in plants may be explained by protective mechanisms that regulate their intakes.

The biological absorption coefficient of V, Ti, Ni, Cu, Cr was increased in Chernyayevsky forest. It shows the high concentrations of these elements in pine needles compared to soil.

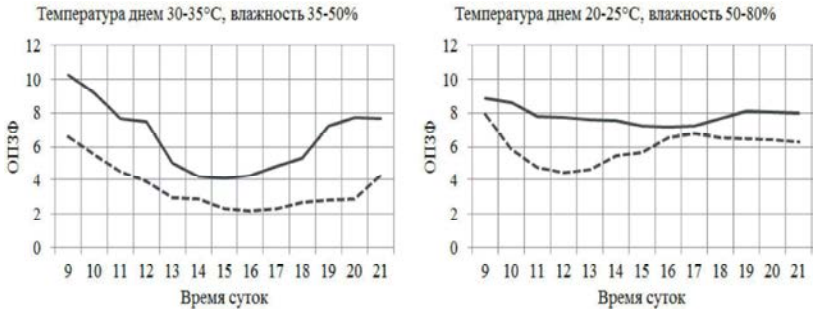


Fig. 1: Daily change of chlorophyll fluorescence relative rate under different weather conditions

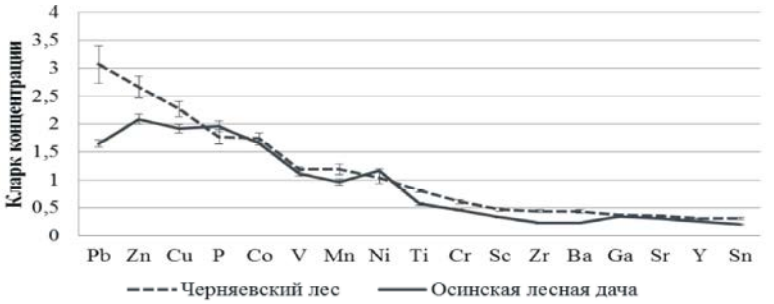


Fig. 2: Clarkes of element concentrations in soil

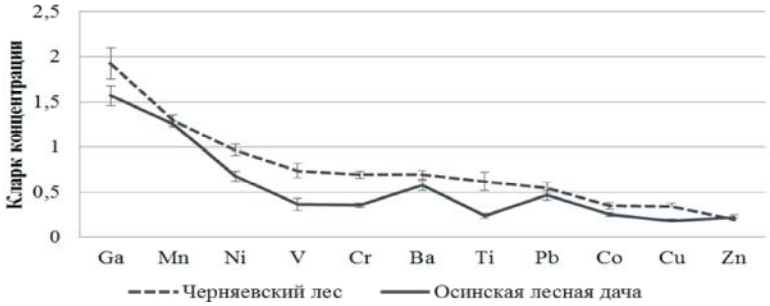


Fig. 3: Clarkes of element concentrations in Scots pine needles

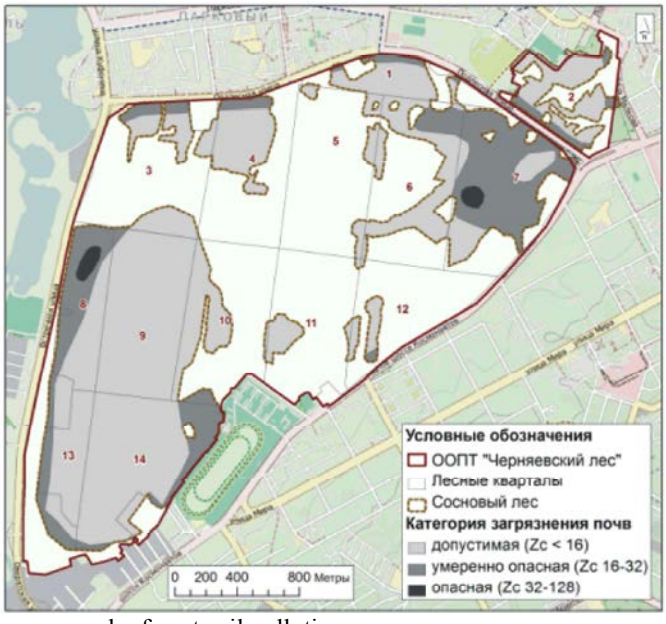


Fig. 4: Total index of Chernyayevsky forest soil pollution

Table 1: Values of chlorophyll fluorescence relative rate, background fractions

| Chernyayevsky forest | | | | | | Osinskaya forest cottage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PP No | RRDF | PP No | RRDF | PP No | RRDF | PP No | RRDF | PP No | RRDF | PP No | RRDF |
| 1 | 0,90 | 11 | 1,03 | 21 | 0,77 | 1 | 1,19 | 11 | 1,15 | 21 | 0,85 |
| 2 | 0,94 | 12 | 1,02 | 22 | 0,98 | 2 | 1,35 | 12 | 1,12 | 22 | 0,83 |
| 3 | 0,60 | 13 | 0,63 | 23 | 0,76 | 3 | 1,25 | 13 | 0,93 | 23 | 0,54 |
| 4 | 0,65 | 14 | 0,74 | 24 | 0,92 | 4 | 1,30 | 14 | 0,89 | 24 | 1,00 |
| 5 | 0,59 | 15 | 0,52 | 25 | 0,89 | 5 | 0,98 | 15 | 0,98 | 25 | 0,89 |
| 6 | 0,44 | 16 | 0,76 | 26 | 0,82 | 6 | 1,20 | 16 | 0,97 | 26 | 0,72 |
| 7 | 0,57 | 17 | 0,79 | 27 | 0,84 | 7 | 0,97 | 17 | 0,48 | 27 | 0,87 |
| 8 | 0,57 | 18 | 0,66 | 28 | 0,89 | 8 | 1,02 | 18 | 0,49 | 28 | 0,80 |
| 9 | 0,64 | 19 | 0,75 | 29 | 0,64 | 9 | 0,91 | 19 | 0,63 | 29 | 0,86 |
| 10 | 0,92 | 20 | 0,70 | 30 | 0,61 | 10 | 0,82 | 20 | 0,69 | 30 | 0,78 |
| | Average RRDF | | | 0,75 ± 0,3 | | Average RRDF | | | | 0,92 ± 0,4 | |

Table 2: Accumulation of microelements in Chernyayevsky forest soils

| Value | Cr | Mn | V | Ti | Cu | Zn | Pb | Ag | Sr | Sn |
|---|---|---|---|---|---|---|---|---|---|---|
| AAV (t/km²) | 18.2 | 114.7 | 4.9 | 657.8 | 4.2 | 17.2 | 8.5 | 0.05 | 8.8 | 0.6 |
| RAV | 0.20 | 0.14 | 0.04 | 0.25 | 0.11 | 0.16 | 0.52 | 0.60 | 0.09 | 0.32 |

Table 3: Transformation of studied SPNA ecosystems from 1975 to 2010

| | | Area | |
|---|---|---|---|
| Observed changes | Main transformation trend | ha | % |
| Chernyayevsky Forest | | | |
| Coniferous forests area reduction | Degradation | 46.0 | 6.7 |
| Broad-leaved forest area increase | Restoration | 34.7 | 5.0 |
| Forest clearing area reduction | Restoration | 30.9 | 4.5 |
| Disturbed lands area increase | Degradation | 32.9 | 4.8 |
| Anthropogenic objects area increase | Degradation | 9.3 | 1.4 |
| Osinskaya forest cottage | | | |
| Coniferous forests area reduction increase | Restoration | 1477.6 | 11.9 |
| Broad-leaved forest area increase | Restoration | 1425.5 | 11.5 |
| Mixed forest area increase | Restoration | 1882.7 | 15.2 |
| Forest clearing area reduction | Restoration | 135.6 | 1.1 |
| Swamp areas increase | Degradation | 59.9 | 0.5 |
| Anthropogenic objects area reduction | Restoration | 948.0 | 7.7 |

Thus, geochemically anthropogenic impact is reflected in elevated concentrations of microelements in soil and assimilation organs of plants. In pine ecosystems the influence of human activity leads to the more than 2-fold accumulation of Pb and Zn in soil relative to soil clarke. Also a significant effect is expressed by Cu, Mn, Ba, Sn, Zr and Ag concentrations increase.

The significant concentrations of Ni, Cr, V, Ti, Cu and Ga in Scots pine needles are observed at anthropogenic load increase.

In order to study the dynamics of SPNA ecosystems Landsat satellite pictures were used made in 1975, 1990 and 2010. According to the results of remote sensing data (RSD) interpretation 5 classes of objects in Chernyayevsky forest and 6 classes in Osinskaya forest cottage were determined. The dynamics of changes was determined for each class during the study period, its causes, spatial and temporal characteristics were revealed.

Ecosystem dynamics was determined by the analysis of selected classes and maps of differences drawing up that are based on the image spectral brightness change.

An increase of surface reflectivity is recorded due to the violation of vegetation in some areas. It is related to logging, the construction of anthropogenic objects, the change of coniferous forests structure, recreation areas development, etc.

The reduction of image brightness is related to natural overgrowth of disturbed lands, artificial regeneration of pines and spruces, as well as to different reflection of anthropogenic objects by brightness.

Acording to RSD decoding results there the areas of revegetation and its degradation on both territories under the influence of anthropogenic activity (Table 3).

In general Chernyayevsky forest since has been degraded since 1975. The degradation is caused by the construction of various buildings, engineering facilities, recreational areas development. The most degraded areas are on the periphery, in recreational areas and in the areas of adjacent land use. The restoration is caused by natural regeneration of broadleaved species, primarily by birch planting at the clearings in the woods.

Osinskaya forest cottage is being restored. Significant areas of cuttings are renewed naturally (by broadleaved species) and by conifer planting. The degradation is due to recreational exposure and swamping, largely caused by Votkinsky reservoir construction.

The vegetation NDVI index is calculated to determine the productivity of pine forests ecosystems. The maximum value of NDVI is an indicator of the maximum amount of vegetation biomass cover. The vegetation index is calculated for both areas by satellite Landsat 7 image ETM + (15 m resolution, the shooting date is 07.08.2012). Missed lines associated with the failure of Scan Line Corrector (SLC) device in ETM+ tool are filled with the data from a similar sensor with the shooting date of 12.08.2011.

The average value of NDVI vegetation index for pine ecosystems among the sample sites of Chernyayevsky Forest makes 0,62 (± 0,1) and the same index for Osinskaya forest cottages makes 0,67 (± 0,1). Thus, this value is 0.5 higher on the background territory and it is considered as a significant factor as the standard value of vegetation index for pine forests makes 0.6 - 0.7.

Anthropogenic load increase changes the natural environment quality. The ecosystems of pine forests are transformed towards degradation. At the early stage of degradation the rate of photosynthesis and productivity of woody plants reduces. The changes are explained by the accumulation of some microelements in soil and Scots pine needles. The revealed mechanism allowed us to determine not only the transformation of ecosystems at SPNA in general, but also local anomalies.

The key marked indicators of pine forests ecosystem transformation within the study areas are presented by Figure 5. Significant differences of ecosystems identical by origin are revealed and described by identified indicators. Each parameter has a defined background value, the significant deviation from which testifies to anthropogenic impact.

The results of the local anomalies analysis allowed to allocate significantly transformed lands. Most degraded ecosystems were presented by three test areas of Chernyayevsky forest that are in close proximity to highways. They are characterized by a moderately dangerous and dangerous levels of soil contamination with the contamination of needles by heavy metals (Ni, Ti, Zn, Cr, V), lower values of the vegetation index and the relative rate of chlorophyll fluorescence. The ecosystems of six sites are also significantly degraded due to the proximity of sites to anthropogenic facilities and recreational areas. The least degraded ecosystems are located at six test areas of Chernyayevsky forest within the special protection area. These areas are influenced mainly by recreational factor.

The most degraded ecosystems at the test sites of Osinskaya forest cottage are presented two sites in close proximity to the road of regional significance. Ecosystem degradation is also noted at four sites exposed to recreational and other factors. The least degraded ecosystems are located on twelve sample sites of Osinskaya forest cottage all measured indices at which are within the background.

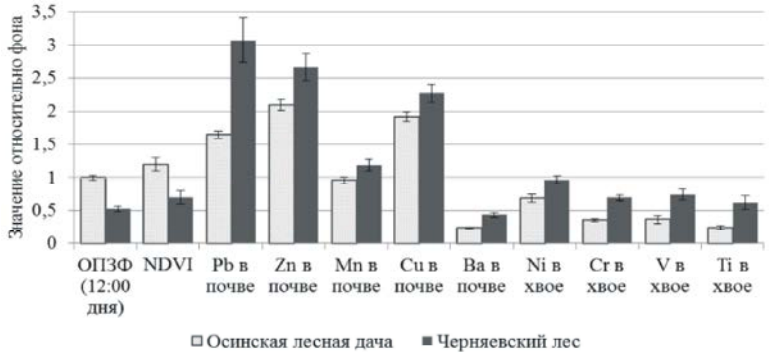


Fig. 5: Indicators of anthropogenic transformation for pine forest ecosystems

## CONCLUSIONS

The delayed fluorescence of Scots pine chlorophyll assimilation is significantly reduced under anthropogenic impact. In pine forest ecosystems anthropogenic effects lead to an accumulation of Pb, Zn, Cu, Mn, Ba, Sn, Zr and Ag in soil and to accumulation of Ni, Cr, V, Ti, Cu and Ga in Scots pine needles. The landscape-indicator analysis of remote sensing data allows to determine the transformation phase of SPNA ecosystems. The complex diagnostics of anthropogenic transformation enables to prevent harmful effects on the environment based on the detection of ecosystem reversible functional changes.

According to the results of eco-geochemical diagnostics the recommendations are proposed concerning the use of selected indicators in environmental monitoring and the environmental control. The environmental monitoring programs are developed for investigated SPNA.

Besides, environmental measures that will optimize the state of SPNA areas and reduce the impact of anthropogenic factors were proposed on the basis of diagnosis.

The conduction of recommended environmental measures will prevent or reduce the harmful effects on the environment. The results of environmental monitoring, including the identification of reversible functional ecosystem changes should be the basis for decision-making.

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