

PAPER • OPEN ACCESS

Problems of landscaping urbanized territory

To cite this article: G A Sorokina *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **315** 052054

View the [article online](#) for updates and enhancements.

Problems of landscaping urbanized territory

G A Sorokina, O A Kuznetsova and N A Ligaeva

Siberian Federal University, 79 Svobodny ave., Krasnoyarsk, 660041, Russia

E-mail: sorokina_gas@mail.ru

Abstract: The paper is concerned with the features of impact of man-induced air pollution on seasonal changes of wood plants for solution of the problem of planting a major industrial city in Siberia. The results of studies of the impact of air pollution components on plants at the stage of winter dormancy are presented. To estimate the depth of the plants winter dormancy a contemporary method of recording the curves of thermally induced changes in a zero level of fluorescence (TCZLF) of phelloderm has been used. The reduction of the period of the dormancy state for wood plants at the growth of the level of anthropogenic impact has been demonstrated. According to the correlation analysis results, the highest effect has been noted for nitrogen dioxide and benzo(a)pyrene. The identified features of the environmental and physiological state of wood plants in the conditions of a city shall be accounted for in the practice of green construction of a city for creating an optical favourable urban environment and maintaining the health of the population of urbanized areas.

1. Introduction

The problems of urbanization and environmental safety, as well as worsening of the life conditions of the urban population have become of global nature recently. In many cities of Russia transition of the center of “environmental disaster” from the industrial zone to central densely populated areas, where the atmospheric pollution index values appear to be several orders higher, is noted. This situation results in the need of deep studies of processes occurring at urbanized areas for the purpose of solving the problem of assurance of the urban environment high quality, city and environment equilibrium; creation of scientifically justified systems for environmental arrangement of the city [1, 2, 3].

Stable optimization of the urban environment is possible only by means of planting. In cities plants are a necessary element of architecture, simultaneously fulfilling the important functions of maintaining the environmental quality, forming a microclimate at the urbanized area and ensuring population protection against unfavourable climatic impact [4, 5]. A green space is one of the efficient means for improving the environmental conditions in cities both in terms of the results and periods of fulfillment and the cost. The role of a green space in mitigation of the adverse environmental impact consists in its ability to level down the factors of natural and man-induced origin unfavourable for a human. Wood plants clean, humidify and enrich the atmosphere of cities with oxygen, change the radiation and temperature conditions, and reduce the wind and noise force [6, 7, 8].

While fulfilling the protective, sanitary and hygienic, architectural, economic and other functions, a green space bears a huge load. To ensure environmental optimization and maintain the quality of the urban environment at a specific level it is necessary to possess sufficient information on the environmental and physiological condition of wood plants, which will allow evaluating their functional contribution in the environmental state improvement [9].



Man-induced pollution of the environment changes many evolutionarily formed complexes of adaptive reactions of plants to living conditions. Violation of the natural dynamics of wood plants transition to the dormancy state and leaving it is one of possible manifestations of such impact [10, 11]. In severe winter conditions accompanied by long-term and intensive wind gusts, the plants, which have not completed transition to the dormancy state, continue losing water but cannot compensate these losses due to deep freezing of the soil cover. During this period, there is a high probability for plants to die as a result of intensive drying [12, 13]. Since evolution of vegetation occurred in the conditions of quite pure atmospheric air, the modern plant species, including wood ones, do not have a specific fitness to the effect of toxic gases of an industrial city, causing significant changes of adaptive reactions to different natural stressors, including low negative temperatures [14].

The purpose of this work is to study the features of impact of man-induced air pollution on seasonal changes of wood plants for solving the problem of planting a major industrial city.

2. Setting the research objectives and discussing results

Plants in urbanized conditions are exposed to a complex set of various environmental factors. This work is based on the materials of research on the influence of air pollution components on woody plants growing within the City of Krasnoyarsk - the largest economic and industrial transport and logistics center in Siberia [15].

Phelloderm tissues taken from non-lignified shoots of balsam poplar (*Populus balsamifera* L.) growing in areas of the city with variable anthropogenic load (territory near the pharmaceutical enterprise OJSC "Kraspharma", territory near a large heat and power plant KrasHPP, Predmostnaya square with heavy auto traffic load, and as a control object - the Park of flora and fauna "Rojev ruchey") were used as an object of studying the effects of anthropogenic air pollution on seasonal changes in wood plants in an urbanized territory.

A contemporary method of recording the curves of thermally induced changes of the zero level of fluorescence (TCZLF) for the chlorophyll-containing cells of phelloderm was used to estimate the depth of the plants winter dormancy [16]. Individuals of approximately the same age, visually intact and located in the same lighting conditions, were selected for the research. During the first day after the collection of samples, curves of thermally induced changes in the zero level of fluorescence (TCZLF) of plants were recorded. The zero level of fluorescence is recorded in the position when all the reaction centers of PS2 were in the oxidized state - "opened". The theoretical basis for applying the method of recording thermally induced changes in the zero level of fluorescence to assess seasonal changes in the state of the photosynthetic apparatus was a change in the aggregation of its components, manifesting in the qualitative and quantitative differences in the TCZLF curves during the summer and winter periods.

During the period of active metabolism, two peaks were recorded on the TCZLF curves: low-temperature peak (50-55° C), associated with the inactivation of the reaction center of the photosystem (PS) 2; and high-temperature peak (65-70° C), caused by "heating up" of the chlorophyll-protein complex of photosystem 1 during the inactivation of its reaction centers. On the TCZLF curves during the winter dormancy period, the low-temperature peak is absent, the position of the high-temperature maximum shifts to higher temperatures (68-73° C), and the intensity of the high-temperature peak relative to the initial fluorescence level (at 30° C) increases.

The TCZLF of phelloderm (wintering chlorophyll-containing tissue) was recorded using the fluorimeter "Photon-11", where fluorescence was induced using light with a wavelength of 435-480 nm. The samples immersed in water were heated at an average rate of 8°C / min in the range from 35° C to 80° C. As an indicator of the state of plants and the depth of the dormancy the ratio of low- and high-temperature maximums of fluorescence intensity on the TCZLF curve (coefficient R_2) was used as an indicator of the depth of dormancy ($R_2 = F_{lht} / F_{lft}$). The visual view of the curves was also taken into consideration [19]. For the period of winter dormancy, this ratio was 0.02, increasing upon the transition of plants to active metabolism up to 1.8.

The ratio of low and high temperature maxima (R_2) on the TCZLF curves was used as an indicator of the transition of plants to the state of winter dormancy. When studying the annual dynamics of R_2

there was a decrease in values for all test areas from four different city districts in the period from September to January, with further growth in the spring months.

It was shown that balsamic poplar plants, growing in areas with man-induced air pollution, become winter dormant later as compared to trees in unpolluted areas. The differences ranged from 7 days to 20 days for the areas with different levels of atmospheric pollution.

A more rapid growth of the fluorescent index R_2 in the spring period was noted for plants from areas with a higher level of atmospheric pollution. According to the theoretical point of view, that indicates an earlier transition to active metabolism. At the same time, plant damage may occur in ecologically polluted areas, when, after short-term thaws, they prematurely leave the state of winter dormancy.

The time lag in transferring to winter dormancy corresponds to the level of atmospheric pollution, which was assessed based on the results of physicochemical analysis of swabs from the balsamic poplar leaves growing within the city of Krasnoyarsk, in areas with different anthropogenic impact (table 1).

Table 1. Results of physical and chemical analysis of balsamic poplar leaf swabs

Test area	pH	Optical density	Electrical conductivity, relative units	Timing shift of winter dormancy
Park of flora and fauna "Roev ruchey"	6.2± 0.1	0.06±0.01	0.17±0.01	Control
Heat and power plant KrasHPP	6.0± 0.1	0.32±0.01	0.48±0.01	6 days
Pharmaceutical enterprise OJSC "Kraspharma"	6.0± 0.1	0.34±0.01	0.54±0.01	13 days
Predmostnaya square	5.4± 0.1	0.40±0.01	0.72±0.01	20 days

To identify the dependence of the dynamics of the plants dormancy state on environmental factors in four districts of the city, air samples for quantitative chemical analysis and poplar shoots samples to record TCZLF curves were taken simultaneously. Then plants were transferring from dormancy to active metabolism under laboratory conditions.

The given data of quantitative chemical analysis was obtained in the Federal State Budgetary Institution "Center for Laboratory Analysis and Technical Measurements in the Siberian Federal District" - a branch of CLATM in the Yenisei Region, which is a subordinate organization of the Federal Service for Supervision of Natural Resource Usage (Rosprirodnadzor).

To characterize the total contribution of individual impurities in the total level of atmospheric pollution in each area of the city, the air pollution index (API_5) was calculated. It allows comparing the levels of atmospheric pollution in different areas polluted with various substances. The calculation of the atmospheric pollution index was performed based on the average daily concentrations of 5 components: suspended solids, benzo(a)pyrene, nitrogen dioxide, sulfur dioxide, and carbon monoxide. The correlation analysis was carried out to identify the relationship between the recorded fluorescent parameter - the ratio of low and high-temperature maxima at TCZLC curves (R_2) and the indicators characterizing the level of environmental pollution in the test areas. The correlation coefficient calculated for the R_2 and API_5 indicator was 0.904, which indicates a strong positive correlation. The correlation between the R_2 indicator and suspended matter is medium and of reverse direction (-0.35). High values of the correlation coefficient were obtained for R_2 and nitrogen dioxide (0.98), benzo(a)pyrene (0.83), which indicates a strong correlation between these values.

The high level of air pollution at a significant area of Krasnoyarsk is associated not only with the transfer of harmful substances from the emission area, but also with the meteorological conditions of

accumulation of impurities. It is characterized by weak winds, which are observed in winter in 30–55% of cases, as well as surface inversions and air stagnation. A temperature factor affects the dynamics of winter dormancy of plants. Therefore, simultaneously with sampling of atmospheric air, temperature and other meteorological parameters were measured in the test areas. The comparison of the obtained values of the correlation coefficient with the complex atmospheric pollution index (0.904) suggests that the R_2 dynamics largely depends on the level of atmospheric pollution than on temperature differences in the test areas (0,381) (figure 1). Considering the influence of the studied pollutants on the state of plants, the greatest effect was noted for the components of the vehicle exhaust gases - nitrogen dioxide (correlation coefficient of 0.98) and benzo(a)pyrene (correlation coefficient of 0.83).

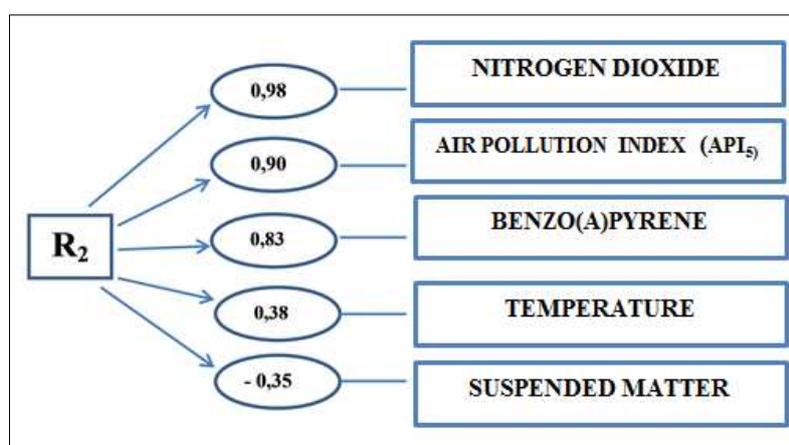


Figure 1. Structure of correlations.

In the ongoing studies species specificity was also determined. The late transition to the winter dormancy state and early leaving it under the conditions of man-induced pollution were shown for both angiosperms (hanging birch *Betula Pendula* Roth., ash maple *Acer negundo*, balsamic poplar *Populus balsamifera* L.), and for conifers (Siberian larch *Larix sibirica* Ledeb., Siberian spruce *Picea obovata* Ledeb.). Obviously, reducing time and depth of dormancy are a universal response of wood plants to an increase in man-induced pollution.

3. Conclusions

A green space fulfills important functions of neutralization and mitigation of negative impacts of industrial urban zones on the population and environment. The vegetation planted in urban streets and in squares, in addition to the architectural, decorative-planning and recreational function, also fulfills a very significant protective, sanitary and hygienic role.

Since evolution of vegetation occurred in the conditions of quite pure atmospheric air, the modern plant species, including wood ones, do not have a specific fitness to the effect of toxic gases of an industrial city, causing significant changes of adaptive reactions to different natural stressors, including low negative temperatures [14].

For the plants of moderate and northern latitudes the transition to the dormancy state in the period of temperature reduction is of specific value for preservation of viability (if the plant hasn't passed the period of dormancy, later its growth rates decrease, fruitage is worsened, and stability is reduced).

The data received shows that trees growing in polluted areas of a city transfer to the dormancy state later and leave it earlier. Their depth of dormancy is shallower throughout the entire winter period. The incompleteness of processes of transition to a dormancy state and the water deficit formed as a result explain drying of trees in the areas with a high level of air pollution and their especially strong damage in winter. Plant damage may occur in ecologically polluted areas, when, after short-term thaws, they prematurely leave the state of winter dormancy.

The method of recording thermally induced changes in a zero level of fluorescence can be widely applied for comparison of the species sensitivity of wood plants to man-induced impact for selection of plant species most resistant to the anthropogenic stress, used for mass planting of cities.

The identified features of the environmental and physiological state of wood plants in the conditions of a city shall be accounted for in the practice of green construction of a city for creating an optical favourable urban environment and maintaining the health of the population of urbanized areas.

References

- [1] Bezrukikh V A, Kuznetsova O A, Ligaeva N A and Makarova L G 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **463**(4) 42055
- [2] Khusnutdinova S R 2005 Urbanized Territories as Object of Strategic Planning and Management *Modern Problems of Science and Education* **2**
- [3] Divakova M N and Lukinykh G L 2015 Landscape Architecture Technique for Creation of a Stable Natural Wireframe of Modern Major Post-Industrial City in the Middle Urals *Modern Problems of Science and Education* **2**
- [4] Goryshina T K 1991 *Plants in a City* (Leningrad: LSU Publishing House)
- [5] Kulakova S A 2012 Evaluation of the State of Urban Green Space *Geographical Bulletin* **23**(4) 34-321
- [6] Bukharina I L 2008 Environmental and Biological Features of Adaptation of Wood Plants in the Conditions of Urban Environment *Izvestia of Samara Scientific Center of the Russian Academy of Sciences* **2** 608
- [7] Neverova O A 2010 Using Phytoindication for Environmental Pollution Assessment *Biophysics* **1**(1) 82-92
- [8] Kramer P D and Kozlovski T T 1983 *Physiology of Wood Plants* (Moscow: Lesnaya promyshlennost) p 464
- [9] Yakushkina N I 1993 *Physiology of Plants* (Moscow: Prosveshcheniye)
- [10] Huttunen S, Havas P and Laine K 1981 Effects of Air Pollutants on Wintertime Water Economy of the Scots Pine (*Pinus sylvestris* L.) *Holarctic Ecologi* **4** 94-101
- [11] Santarius K 1973 The Protective Effect of Sugars on the Chloroplast Membranes during Temperature and Water Stress and its Relationship to Frost Desiccation and Heat Resistance *Planta* **113** 105-14
- [12] Usmanov I Yu, Rakhmankulova Z F and Kulagin A Yu 2001 *Environmental Physiology of Plants* (Moscow: Logos)
- [13] Gayevsky N A, Sorokina G A, Gold V M and Mirolubsky I V 1991 Seasonal Changes of Photosynthetic Apparatus of Wood and Bush Plants *Physiology of plants* **38**(4) 685-92
- [14] Sorokina G A and Lebedeva V P 2011 Bioindication of Atmospheric Pollution with the Use of Wood Plants *Environmental Protection and Nature Management* **2** 52–6
- [15] Downton W J S and Berry J A 1982 Chlorophyll Fluorescence at High Temperature *Biochim Biophys. Acta* **679**(2) 474-86
- [16] Sorokina G A, Lebedeva V P and Pakharkova N V 2016 *Influence of Air Pollution on the Seasonal Changes in Woody Plants Abstract Book: 5th International EcoSummit Ecological Sustainability: Engineering Change France, Montpellier* p 2079