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Research Article

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Impact of Heavy Metals on Vegetation Communities with *Plantago Major* L and *Plantago Media* L

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ABSTRACT

Due to the huge development of gas and oil industry in Tobolsk town, Tyumen region, the anthropogenic load on the environment increases. The main pollutants are heavy metals. Impact of heavy metals leads to the changes in the environment and influences the vital functions of the plants. The study of the plants' reaction on the heavy metals pollution is one of the up-to-date tasks. It is important to know how the contaminants impact on the plants' chemical constitution. In this research were studied the flexibility of lead morphometric parameters of Plantago major L. and Plantago media L. depending on the anthropogenic impact were considered the interconnection between the rise of the reaction load and the changes in the nature and structure of herb stratum. Among the pollutants that are accumulated in plants P. major L. and P. media L., were selected the group of the following heavy metals (As, Cr, Cu, Mo, Ni, Pb, Sr, Zn). The analysis of plants' samples has been done using the method of inductively coupled plasma with atomic emission spectrometer OPTIMA-7000DV of PerkinElmer Company (USA). The result of the research showed that P. major L. and P. media L. are sensitive markers for the assessment of environmental quality. It is shown in the changes of their morphometric parameters. During the research work were defined that the plants' capacity to accumulate heavy metals is different. The results showed that Plantago major L. accumulates Cr, Zn and Plantago media L. accumulates As, Cr, Cu, Pb Sr.

Keywords: *Plantago major* L.; *Plantago media* L.; Heavy metals pollution; Morphometric parameters; Ontogenesis

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INTRODUCTION

The strong anthropogenic impact on the environment will require systematic observations of the environmental pollution. The observation system should include the following procedures: the selection of the observed object; examination of the object; its evaluation. This will allow to assess the indicators of ecosystems' condition, the state of the human environment and to evaluate the damage [1,2].

The active use of biological methods for the estimation of anthropogenic disturbances is connected with the response of vegetation to any deviations in the environment from the normal parameters. This reaction allows us to estimate the anthropogenic impact using indicators that have a biological meaning, and often those which can be transferred to humans [3,4].

Species of plantain type are the most typical representatives of urban flora and synanthropic vegetation that are widespread and play a specific role in ruderal plant communities. Among the plants it is convenient to use the cenopopulation *Plantago major* L. and *Plantago media* L. as anthropogenic species with wide geographic spread and mostly seed reproduction. In this regard was used *Plantago media* L. and *Plantago major* L. as objects of study. Besides these species have medical value [5,6].

The baseline study of the environment shows a tendency for the accumulation of chemical substances that impact the biological systems. Every year the anthropogenic pollution of Tobolsk town and Tobolsk region territories is increasing [7,8].

Considering all mentioned above, in the region of petrochemical and oil-chemical industries, the research of the changes in plants population that are subject to different kinds of pollution within the system: soil-plant is important both from theoretical and practical point of view [9-11].

MATERIALS AND METHODS

Sites Selection

At the stage of field research works were defined the areas with different kinds of anthropogenic impact where were considered the certain parameters of top-priority pollutants. Site № 1 – the eastern part of the town that is attached to the industrial area of Tobolsk Petrochemical Plant, Tyumen region, Russia; model site № 2 – roadside attached to the industrial area of Tobolsk Milk Production Plant, Tyumen region, Russia; model site № 3 − test area, the edge of mixed forest close to Vinokurovo Village (Tobolsk region, Tyumen region, Russia), model site № 4 – the northern part of Tobolsk town, wastelands adjacent to the industrial area of Tobolsk Precast Plant, Tyumen region', Russia; model site № 5 − roadside, the southern part of Tobolsk town, Tyumen region near Nikolsky uphill road; model site № 6 – modern residential area №9, densely built-up multistoried urban area.

Morphometric Parameters

While studying the cenopopulations of *P. major* L. and *P. media* L., the plant samples have been taken from test areas with different kinds of anthropogenic impact. During the ontogenesis at each site for 25 plants of different age were considered the basic statistic parameters of morphological peculiarities. In this study were considered the following ontogenesis stages: jewellery (j), immature (im), virginile (v), young generative (g_1), middle-aged generative (g_2), old generative (g_3) [12-14]. During the ontogenesis were considered the morphometric parameters of *P. major* L. and *P. media* L. As a result, the correlation coefficient between the basic morphological traits for *P. major* L. and *P. media* L. has been defined.

Types of Soils

A field soil survey was conducted in summer 2015. The correspondence of soil types to geomorphological elements, orographic level and classification units of vegetation cover was taken into account during the survey. Soils were studied on the basis of soil profiles. Cuts were made to the full depth of 1.5 m to detect and study a soil-forming rock.

Sampling

Soil samples were taken and prepared for quantitative chemical analysis in accordance with [15]. Five samples were taken from each plot.

Sample Preparation

The samples were prepared using the speedwave MWS-2 microwave digestion system manufactured by PerkinElmer (USA). The soil sample (m=4.0 g) was placed in a plastic tube. HNO_3:HCl=1:3 was added to it. 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.

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 H_2SO_4:H_2O_2=1:3 was added. The subsequent decomposition steps were carried out in the same manner as described above.

The quantitative chemical analysis of accumulated heavy metals and trace elements (As, Cr, Cu, Mo, Ni, Pb, Sr, Zn) 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. Mathematical data processing has been carried out with common methods using Microsoft Excel package.

RESULTS AND DISCUSSION

According to the total quantity of grown plants the sites have been placed in the following order: №3 − 373, №6 − 244, №5 − 208, №1 − 179, № 2 − 175 and №4 − 173 burgeon exemplars.

Approximately in the same order the sites have been split by species diversity: Site № 3 − 25 species, Site № 6 −22, Site № 5 and №4 – 19 species, Site № 2 − 17, Site № 1 − 15 plant species. There are 19 plant species both on Sites 4 and 5, 12 out of 19 are found overlap. In all vegetation communities the supremacy is taken by three species: *Plantago major* L., *Plantago media* L., *Polygonum aviculare* L.

In general *Plantago major* L. and *Plantago media* L. are found with 30 other plant species. On sample areas the number of these types ranges from 173 to 373 exemplars. Anthropogenic impact leads to the decrease of plant exemplars on highly-polluted areas.

The Analysis of Leading Bloodlines

The analysis of leading bloodlines has shown that on the control site the percentage of *Plantaginaceae* is 34.6%. *Poaceae is* 14.7%. On Site 6 with the medium rate of pollution prevail the bloodline *Plantaginaceae* − 32.4%; Poaceae – 16.7%. On the area with high rate of pollution the plants of bloodline *Plantaginaceae* amount to 32.2%. *Poaceae* –18.1%. The plants of bloodline *Polygonaceae are equal to* 15.5% and bloodline *Asteraceae* − 13.2%.

Upon the increase of anthropogenic impact were noticed the increase in plants of bloodlines *Poaceae* and *Polygonaceae* and the decrease of plants' bloodlines *Asteraceae and Fabaceae*.

Upon the analysis of ecological group's ratio it was defined that the anthropogenic impact on the Sites leads to the increase of plants with xeromorphic structure (xeromesophytes). On the control site the portion of plants with the xeromorphic structure is 41% out of the total number of specimen, on a highly-polluted area (№1) − 13%. In general this statement corresponds to the anthropogenic pollution data of model sites in our research. The comparison of vegetation communities' species composition in six areas depicts the impact of pollutants on the formation of vegetation communities on the one hand. On the other hand it indicates the ambiguous adaptive response of different kinds of plants on a set of ecological conditions on model sites.

Variability of morphological traits is unidirectional for both plant species. In juvenile (j), immature (im) and virginile (v) conditions the morphological traits of *P. major* L. and *P. media* L. vary slightly on all six areas.

Morphological cenopopulation parameters of *P. major* L. and *P. media* L. vary a lot. Intensive man-caused impact leads to the decrease of middle-size species (*P. major* L. and *P. media* L.), that can be also seen in all morphometric parameters. Establishing the correlation coefficient among the main morphological traits both for *P. major* L. and for *P. media* L. helps to conclude that the interdependence between them goes down with the increase of anthropogenic load.

Also were defined the content of the following heavy metals in the soil on the mentioned sites (As, Cr, Cu, Mo, Ni, Pb, Sr, Zn). In soil that is subject to man-caused pollution, the heavy metals data are the following: As from 0,32 to 0,84 (control 0,12), Cr from 1,3 to 5,5 (control 0,9), Cu from 4,35 to 10,5 (control 2,2), Mo from 3,11 to 5,75 (control 2,3), Ni from 2,00 to 5, 5 (control 2,3), Pb from 6,18 to 12,61 (control 1,2), Sr from 3,25 to 9,08 (control 1,36), Zn from 5,22 to 15,23 (control 1,3) mg kg^{-1} (Figure 1).

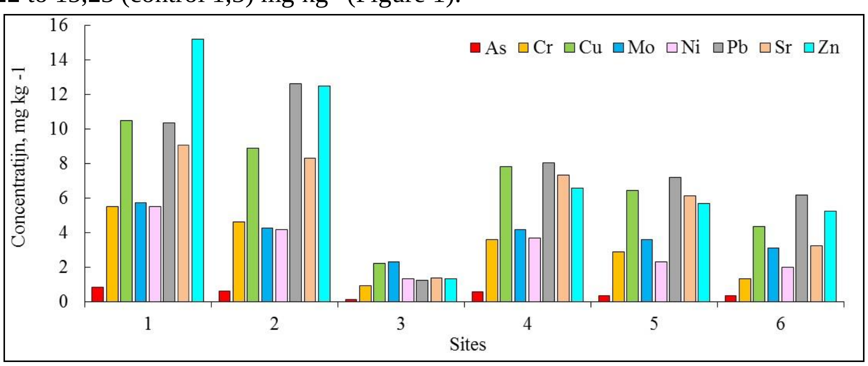

Figure 1: The content of heavy metals in the soil on the observed areas (1 - site No. 1, control; 2 - site No. 2; 3 - site No. 3; 4 - site No. 4; 5 - site No. 5; 6 - site No. 6)

Heavy metals are accumulated not only in soil, but also in plants. Using chemical analysis of total plants biomasses (P. *major* L. and P. *media* L.) were defined the incorporation rate of analyzed chemical elements (Figure 2).

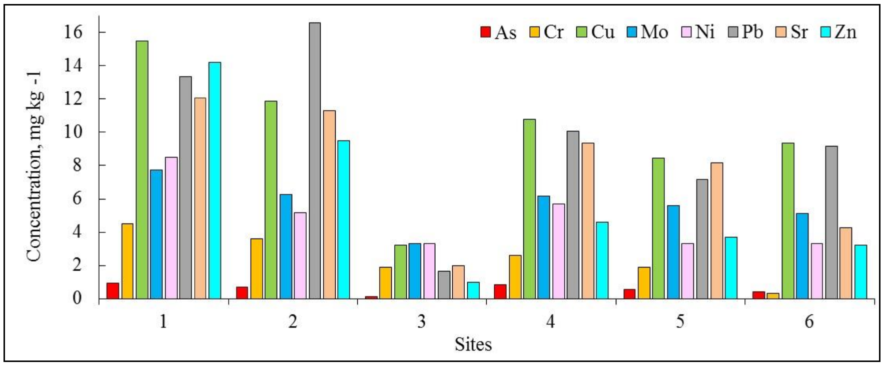

Figure 2: The content of heavy metals in the plant *P. major* L. (1 - site No. 1, control; 2 - site No. 2; 3 - site No. 3; 4 - site No. 4; 5 - site No. 5; 6 - site No. 6)

Zn content in plants on highly-polluted areas varies from 3.22 to 14.23 mg kg^{-1} (*P. major* L.) and from 7.22 to 16.23 mg kg^{-1} (*P. media* L.). The accumulation of copper varies from 8.45 to 15.5 mg kg^{-1} for *P. major* L. and from 2.35 to 8.5 mg kg^{-1} for *P. media L*. The content of Cr, Mo, Ni, Pb, Sr in *P. major L.* was also much bigger than in *P. media* L. (Figure 3).

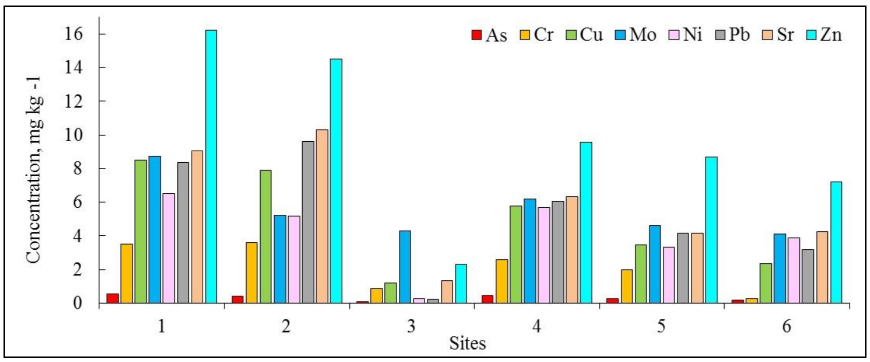

Figure 3: The content of heavy metals in the plant *P. media* L. (1 - site No. 1, control; 2 - site No. 2; 3 - site No. 3; 4 - site No. 4; 5 - site No. 5; 6 - site No. 6)

Upon the results of soil and plants' analysis, the sites can be put in the following order according to the increase of anthropogenic load, including the accumulation of heavy metals in plants: Site №3 (control) → Site № 6→ Site №5→Site №4→ Site №2 → Site №1.

So, it was found that the plants differ according to their capacity to accumulate heavy metals. In all cases *Plantago major* L. incorporates more heavy metals comparing to *Plantago media* L. Out of all studied metals the accumulation capacity of the plants species is the highest with copper (Cu), the lowest - with plumbum (Pb).

Also were defined high positive correlation in concentration of heavy metals in soil and plants (*P. major* L. r=0,58-0,99; *P. media* L. r=0,48-0,98).

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The main reason for the environmental degradation in the urban areas is the increase of the anthropogenic pollution. Among the great variety of pollutants the most toxic are heavy metals. Among the identified pollutants that are accumulated in plants *P. major* L. and *P. media* L., were selected the group of the following heavy metals (As, Cr, Cu, Mo, Ni, Pb, Sr, Zn). Many literature data and the results of our research show that heavy metals cause a great number of changes in plants.

According to the results of our study, the plants of the bloodlines Poaceae and Polygonaceae can be met more often on the polluted phytocenoses than the plants of bloodlines Asteraceae and Fabaceae.

During the ratio analysis of ecological groups were found out that the anthropogenic load of the observed areas leads to the increase of plants population with xeromorphic structure. During the anthropogenic influence, many species fall out of the phytocenoses, others – reduce its quantity. It is confirmed by many authors.

It was noted earlier that the higher concentration of heavy metals in soil leads to the growth retardation of *P. major* L. and *P. media* L. and to the anomalies of morphological characters. There is an individual reaction of separate plants' species on the increase of anthropogenic pollution. In our research it is shown by the changes of morphological characters (mass of the vegetative part of the plant, the root, the length and the width of a leaf) on six ontogenesis stages. Indeed, many studies have pointed out that the excess of chemical elements in soil has its own laws: the increase of heavy metals concentration slows the growth of plants and damages its root system.

Basing on the results of our study it was a correlation between the number of heavy metals in soil and their accumulation in *P. major* L. and *P. media* L. The accumulating capacity is different*: Cr, Zn* are better accumulated by *Plantago major* L. and As, Cr, Cu, Pb Sr are better accumulated by *Plantago media* L.

CONCLUSION

When the anthropogenic impact is changed, the number of plant species decreases. The ratio of the leading families in the vegetation communities is changing. Morphological cenopopulation parameters of *P. major* L. and *P. media* L. vary a lot. Intensive man-caused impact leads to the decrease of morphometric parameters of *P. major* L. and *P. media* L. The most perspective for bioindicative analysis are morphometric parameters of *P. major* L. and *P. media* L. at the ontogenesis stages g_1, g_2, g_3. Considering all morphometric parameters the bioindicative value of *P. major* L. is higher than *P. media* L.

The value of correlation coefficients defines the interconnection of analyzed characteristics; it also depends on changeable environmental conditions. The interconnection becomes considerably weaker with the amplification of a stress situation.

The results of the research help to assess the resistance of vegetation communities to natural and anthropogenic impacts. *Plantago major* L. and *Plantago media* L. can be considered as sensitive markers for the environmental quality assessment. During the research work was marked different heavy metals' accumulative capacity of observed plants. In our research the accumulative capacity varies when it comes to Cr, Zn *(Plantago major* L.) and when it comes to As, Cr, Cu, Pb Sr (*Plantago media* L.).

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