Phytosanitary status of disturbed ecosystems

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Abstract. The research is devoted to the study of the problem of finding plants-remediators, weeds of inconveniences and arable lands of the Orenburg region. Analysis of aboveground organs of representatives of herbaceous flora and soil for the presence of mobile forms of heavy metals (Co, Cu, Cr, Mn, Ni, Cd, Pb, and Zn) by atomic absorption spectrometry using mathematical statistics methods. It was found that the best accumulating abilities are (in descending order): Elytrigia repens (L.) Nevski, Achillea millefolium L., Taraxacum officinale Wigg. We found that the concentrations of the most dangerous heavy metals Pb, Cd are expressed for such potential mediators (in descending order): Elytrigia répens, Achilléa millefólium, Taracsacum officinalis, Plantágo média,Chelidónium május.

1. Introduction

The intensification of many industries has led to anthropogenic pollution and the accumulation of pollutants in the soil. This situation has acquired the status of one of the most important environmental problems of disturbed ecosystems and has led to the development of reclamation technologies [1, 2, 3]. The steppe zone of the Southern Urals is a region with intensive development of industry and transport [4]. Pollutants are present everywhere, they play an important role in maintaining physiological processes in organisms [5, 6] but the increased content of elements in the media leads to the fact that they exhibit toxic properties and interfere with metabolic reactions [5]. Many countries use different methods of cleaning up soil and water contaminated with pollutants. So, since the 1990s, a cost-effective technology of soil purification – phytoremediation has been used. This technique is based on the phenomenon of hyperaccumulation of metals by plants from soil and water [1, 2, 3]. Therefore, the aim of the study is to select remediator plants from among the representatives of the flora of arable land and inconveniences.

2. Materials and methods

Experimental sites are located in Russia in the Orenburg region village Nezhinka 51°46' 06" E 55°21'58" N, Uchkhoz village 51°45'55" E 55°16'02" N. The study sites № 1-2 were laid in the village of Nezhinka, Orenburg region. They are located on the right bank of the Ural River, 9 km east of Orenburg city. Experimental plots № 3-4 were laid in the Uchkhoo settlement of the Orenburg district of the Orenburg region on the right-bank slope of the Ural River Valley, 12 km from Orenburg (see Fig. 1).

2.1. Sample preparation of soil and plant samples

Spot samples were taken using the "envelope" method. 5 soil samples were taken from each point of the controlled area. Plant samples were collected during the growing season on the territory of the
agrophytocenoses *Elytrigia répens*, *Arctium lappa* *L.*, *Chelidónium május*, *Polygonum aviculare* *L.*, *Taracioscum officinalis*, *Achilléa millefólium*, *Plantágo média*.

2.2. Determination of heavy metals
The determination of the heavy metals in the samples was conducted by atomic absorption spectrophotometry (AAS). A Thermo Scientific AAS Model iCE 3000 was used for quantitative analysis of the heavy metals in the samples. The quantitative analysis involved measuring the absorbance of each analyte in the samples and standard solutions. Lead, cadmium, copper, iron and zinc absorbances were measured at wavelengths of 283.3 nm, 228.8 nm, 324.7 nm, 248.3 nm and 213.9 nm, respectively.

2.3. Statistical processing of materials
Statistical analysis of the data was carried out using Statistica 10.0 software packages (Stat Soft Inc, USA). For mathematical calculations, the biological absorption coefficient (\(Ax\)) was used:

\[
Ax = \frac{C_p}{C_s}
\]

\(C_p\) – concentrations of trace elements in the ash of plant material, \(C_s\) – the content of the pollutant in the root of the habitable layer of the soil.

3. Results and discussion

3.1. Results of plant samples research
As a result of chemical analysis in the vegetative part of plants, it was revealed that the concentrations of Cr and Zn constantly exceeded the norm in all plant species throughout the entire observation period. The excess of Zn, Cr, and Cd in *Polygonum aviculare* *L.* was constantly observed. In aerial parts of plants *Cichorium intybus* *L.*, *Plantago media* *L.*, *Taraxacum officinale* *Wigg.* There is a very frequent excess of Zn, Cr, Cd, Pb, Ni relative to the norm. In plant tissues: *Elytrigia repens* (L.)Neveski periodically exceeded the norm in heavy metals such as Co, Cr, Ni, Zn, Pb, and *Arctium lappa* *L.* - Co, Cr, Pb, Cd, at *Artemisia absinthium L.*, *Artemisia vulgaris L.* - Sg, Ni, Zn, Pb, Cd, *Achillea millefolium L.* - Co, Sg, Zn, Pb.

3.2. Results of soil samples studies
As a result of the soil analysis, it was revealed that the Cd concentration in the surface layers of the soil increased over the years, regardless of the site. At all reference sites, the content of Co, Mp was normal. Analysis of studies of Ni concentrations independently of the site revealed a significant content of the parameter in the free state. Over the years, regardless of the study area, Pb concentrations accumulated in the 0-10 cm layer. This distribution of elements in the soil indicates that heavy metals are accumulated by the organic matter of the soil (mainly humic acids), which leads to their detoxification and "disconnection" from the biogeochemical cycle. In the study area, no heavy metal was found to be dominant in the soils.

3.3. Relationship between soils and plants
A biological absorption coefficient \(Ax\) was analyzed. It reflects the relationship of metal concentrations in soils and plants regardless of plant species. We evaluated the propensity of the chemical element to accumulation in the aerial parts of plants. A.I. Perelman [7] registered 5 row elements by the degree of biological absorption by plants. As a result of analysis of studies (table 1), the largest values of the average \(Ax\) data were Zn = 3.99, Pb = 2.85, Cu = 2.69, Cr = 2.23, Ni = 2.12. In reference section № 1, the values were higher in terms of parameters: Cr = 2.28; Co=1.83; Cu =1.73; Ni=1.45; Cd = 1.35 (table 1). Studies of the concentrations of soil pollutants and plants of turnip site № 2 revealed that their concentrations were significantly higher than 1, for example \(Ax\): Pb = 8.4; Cu=5.89 Zn =3.05, Cr=3.02;
Ni = 2.08 (table 1). The ab of aerial parts of plants of the studied site № 3 were increased by the values: 
Zn = 9.37; Co = 4.31; Ni=2.86; Cr=2.11; Pb = 1.78 (table 1). Plant area № 4 increased in terms of the 
following parameters: Zn = 2.14; Cu = 1.85; Cr=1.51.

**Table 1.** Generalized parameters of the coefficient of biological absorption of vegetative plants parts 
and soils in Orenburg region.

| № site number | Elements |
|---------------|----------|
|               | Pb       | Cd | Co | Mn | Cu | Zn | Ni | Cr |
| 1             | 0.71     | 1.35 | 1.83 | 0.54 | 1.73 | 1.43 | 1.45 | 2.28 |
| 2             | 8.4      | 1.22 | 1.56 | 0.39 | 5.89 | 3.05 | 2.08 | 3.02 |
| 3             | 1.78     | 0.66 | 4.31 | 0.61 | 1.3 | 9.37 | 2.86 | 2.11 |
| 4             | 0.54     | 1.09 | 0.71 | 0.83 | 1.85 | 2.14 | 0.86 | 1.51 |
| δa           | 3.73     | 0.29 | 1.54 | 0.18 | 2.14 | 3.64 | 0.85 | 0.62 |
| M±m0         | 2.85±0.19 | 1.08±0.14 | 2.1±0.77 | 0.59±0.09 | 2.69±1.07 | 3.99±1.82 | 1.81±0.42 | 2.23±0.31 |

δa – standard deviation; M±m0 – standard error or error of the arithmetic mean

Mathematical sampling of plant Ax values is in most cases homogeneous. However, single anomalous emissions of Pb, Zn (table 1) were observed. This indicates the presence of a major road junction. Significant accumulation of Zn was observed in most plants. Perelman A.I. [7] determined Zn in 2nd row by chemical capture by plants and attributed this parameter to highly accumulated elements by plant tissues. The average values of Ax are increased for all plant species independent of the study site according to the following parameters: Zn, Pb, Cu, Cr, Ni, Cd. Next, we analyzed the average Ax data of terrestrial plant parts by species and by study sites. Plant species have been demonstrated, when analyzing the average Ax data (table 2), it can be seen that *Elytrigia répens* has the best accumulative properties. Firstly, Pb = 7.63 is deposited in a significant amount - element 5 of the series of weak and very weak capture according to A.I. Perelman [7] (table 2). Secondly, *Elytrigia répens* accumulates many trace elements according to the classification of A. I. Perelman [12] belonging to the 3 series of weak accumulation and average capture, for example Ax: Cu = 7.51; Cd =3.36; Mn = 2.14; Ni = 2.12; Co = 1.02, Zn = 1.24. *Achilléa millefólium* can be attributed to hyperaccumulators, so in the tissues of the terrestrial parts the plant accumulates trace elements: Zn = 10.21; Pb = 4.83; Cu = 3.71; Ni = 2.16; Mn = 2.15; Cd = 1.33; Co = 1.11 (table 2). Of the studied plant species, *Taracsacum officinalis* takes the third place in the accumulation of pollutants. The plant accumulates in a significant amount Ax: Zn = 5.11; Cu = 4.94; Pb = 2.13; Cr = 1.58; Mn = 1.42.

Analysis of averaged data of the relationship between surface layers of soil and plants (table 2) showed that the following plant species have the best accumulating properties of Pb and Cd: *Elytrigia répens* accumulates Ax: Pb = 7.63 and Cd = 3.36; *Achilléa millefólium* accumulates Ax: Pb = 4.83 and Cd = 1.33; *Taracsacum officinalis* Ax: Pb = 2.13 и Cd = 4.13 ; *Plantágo média* Ax: Pb = 3.09 и Cd = 2.22 ; *Chelidónium május* Pb = 3.99.

**Table 2.** Values of the biological absorption coefficient of vegetative plants parts (mg/kg) of 8 plant 
species in the areas in Orenburg region

| Indicators | Planttype         | Pb   | Cd   | Co   | Mn   | Cu   | Zn   | Ni   | Cr   |
|------------|-------------------|------|------|------|------|------|------|------|------|
| δ          | *Elytrigia répens*| 7.91 | 2.57 | 0.56 | 2.03 | 8.92 | 0.59 | 0.96 | 1.38 |
| M±m        | *Elytrigia répens*| 7.63±3.95 | 3.36±1. | 1.02±0.2 | 2.14±1.0 | 7.51 | 1.24±0.2 | 2.12±0.4 | 1.66±0.6 |
Soils are the main source of trace elements in plants. The analyzed relationship between the concentrations of heavy metals in soil and plants indicates the effectiveness of their biosorption and variability (table 2).

4. Conclusion
Series of biological absorption of A.I. Perelman are confirmed and reproduced. Analysed bonds reflecting phytocomputational processes for upper soil horizons are a series of: Zn, Pb, Cu, Cr, Ni, Cd. In the analysis of plants have ability to accumulation (in decreasing order): Elytrigia repens (L.) Nevski, Achillea millefolium L., Taraxacum officinale Wigg. Concentration of the most dangerous among toxic metals Pb, Cd in the soil and plants best of all are expressed for such bioremediator as (in decreasing order): Elytrigia répens, Achillea millefolium, Taraxacum officinale, Plantágo média, Chelidónium május.

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| δ   | Arctium Lappa L | 0.83 | 0.24 | 0.69 | 1.98 | 5.74 | 0.46 | 0.48 | 2.02 |
|-----|-----------------|------|------|------|------|------|------|------|------|
| M±  | Arctium Lappa L | 1.61±0.81±0 | 1.04±0.3 | 1.55±0.9 | 7.63±3.3 | 1.21±0.2 | 1.52±0.2 | 3.14±1.0 |
| m   | Chelidóni május | 4.44 | 0.34 | 0.18 | 0.14 | 3.08 | 0.38 | 0.33 | 1.28 |
| δ   | Cichórium intybus | 3.99±0.33±0.63±0.38±0.30±2.1 | 0.93 | 1.51±0.2 | 3.09±0.9 | 4.61 | 0.9 | 4.25 | 0.95 |
| M±  | Cichórium intybus | 3.14 | 12 | 2 | 0.85±0.7 | 1.73±0.3 | 1.73±0.7 | 0.09 | 0.49 | 0.62 | 1.86 | 1.76 | 0.77 | 0.55 | 0.56 |
| m   | Polygonum aviculare | 0.09 | 0.49 | 0.62 | 1.86 | 1.76 | 0.77 | 0.55 | 0.56 |
| δ   | Polygonum aviculare | 0.07±0.96±0.96±0.154±0.9 | 2.25±0.8 | 1.71±0.3 | 0.91±0.2 | 0.94±0.3 | 0.05 | 28 | 5 | 3 | 8 | 8 | 7 | 2 |
| M±  | Taraxacum officinalis | 3.98 | 5.98 | 0.33 | 2.15 | 5.99 | 4.82 | 0.85 | 0.85 |
| m   | Taraxacum officinalis | 2.13 | 4.13±3.0 | 0.79±0.1 | 1.42±1.0 | 4.94±2.9 | 5.11±2.4 | 1.07±0.4 | 1.58±0.4 |
| δ   | Achillea millefolium | 7.97 | 1.72 | 1.03 | 2.95 | 2.23 | 7.95 | 1.20 | 0.83 |
| M±  | Achillea millefolium | 4.83±1.33±0.11±0.5 | 2.15±1.7 | 3.71±1.2 | 10.21±4.0 | 2.16±0.6 | 1.67±0.4 | 2.17 | 43 | 0 | 9 | 8 | 2 | 1.6±0.42 | 2.09±0.4 |

| δ + – standard deviation; M±m – standard error or error of the arithmetic mean. |
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