Orthoptera insects as bioaccumulators of potentially toxic elements (Ostrava city, Czech Republic)

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Abstract. This paper explores whether orthopteran insects (Orthoptera) may be used to study bioaccumulation of potentially toxic elements in their bodies on the territory of Ostrava City. For the purpose of laboratory analysis, we used a common species Metrioptera roeselii (Ensifera) and Chorthippus parallelus (Caelifera). The laboratory analysis confirmed a bioaccumulation of some potentially toxic elements (Ni, Zn, Cu, Cr), which is probably dependent on the distance of the sources of pollution and main wind direction.

1. Introduction
The reason behind the fact that a half of the world's population lives in urban agglomerations is the economic development. However, excessive industrialization and urbanization lead to an increase in potentially toxic elements that become parts of the urban environment. This influence on the urban environment concerns the air, and urban land in particular [1, 2, 3, 4]. The Ostrava-Karviná agglomeration belongs to the human substances with a high load of potentially toxic elements in the all components of the environment, because it is an important postmining and industry locality in the Czech Republic [5]. Ostrava city has been associated with the extraction and processing of hard coal, and metallurgical and chemical industries [6]. Changes in the composition of animal communities, are connected, with increasing environmental contamination in the industrial agglomerations. Sensitive species have disappeared, and adaptable species have dominated in urban agglomerations, because they have a wide ecological valence [7, 8]. Invertebrates (Avertebrata) are important components of ecosystems. Individual taxa of invertebrates are often used for biomonitoring purposes [9]. The study by Crawford et al. (1996) focused on bioaccumulation and effect of Cu and Cd in the bodies of various terrestrial invertebrates. According to this study, invertebrates are suitable bioaccumulators, because they are in the direct contact with a potentially contaminated environment due to their inclusion in trophic networks and the way of life. Other features, such as the high abundance, sufficient size, relatively easy determination of the taxon and links to various trophic networks, make them an ideal model group [10]. In the Czech Republic there are about 30 thousand insect species (Insecta) in the 25 orders. Each insect order differs from one another due to specific characteristics and varying degrees of possibilities for biomonitoring. In this study, Orthoptera insects are used as a model group. In the Czech Republic there are 96 species, which are divided into 2 suborders (Ensifera, and Caelifera). Straight-winged insect belongs to regular components of fauna in the urban environment. This group of insects is well-researched, except bioaccumulation potentially toxic elements [11, 12].

2. Materials and methods
In this paper we have drawn two lines with the main point source of pollution (ArcelorMittal a. s.) in their intersection. ArcelorMittal a. s. is considered as one of the largest polluters in Ostrava [13]. The direction of the lines corresponded to the wind rose, which was modeled in Symos97. The wind rose was divided into a major axis [southwest (S-W) – northeast (N-E)] and a minor axis [northwest (N-W) – southeast (S-E)]. The main axis was divided into 10 sampling areas, which were 2 km apart (5 sampling areas were located in the both major axes). In the minor wind flow axis, we assumed smaller...
concentrations of potentially toxic elements, therefore only 8 sampling areas (4 sampling areas facing N-W and 4 sampling areas facing S-E) were set. In the minor axis the sampling areas were 2.5 km apart. Specimens of Orthoptera were collected using a sweeping net. On each plot, one of transect was drawn, which included a total of 10 sweeps. The choice of suitable taxa was based on their food biology. In the paper we discuss two model species of Orthoptera with different trophic preferences: *Metrioptera roselii* (order *Ensifera*) and *Chorthippus parallelus* (order *Caelifera*). Each of the species was abundantly represented in the localities. A plant material was collected (Trifolium pratense) in the 4 localities (Na Hrázkách, Rychvald, Lesní and Kaňovice). For the purpose of the laboratory analysis, it was necessary to weigh 0.3 g of biological material, therefore 10 - 15 specimens (according to size or weight). The specimens were taken from each sample area (one laboratory analysis sample). The quantity of specimens was experimentally determined using the species *Acheta domestica*, which were killed, dried, and subsequently the required sample weight was determined for the laboratory analysis (this amount can be quantified to 10 adults). Due to the fact that the results of laboratory analysis (so-called external contamination from swamped particles during sweeping on the surface of plants) could be influenced by slipping, the samples were rinsed with distilled water on 4 sampling areas. The blind sample contained 100 % of distilled water. The decomposition of the biological material was carried out by means of open decomposition in aqua HNO3 + 3HCl. In each sample we added HF in the ratio 3: 1 (3 parts of HNO3 and 1 part of HF). The content of potentially toxic elements in the samples was determined using the flame atomic spectrophotometer method. The apparatus was used contrAA®700 Analytik Jena AG.

### 3. Results

In this paper, we focused on 9 potentially toxic elements, out of which 7 were detected (Table 1). The detected potentially toxic elements are Fe, Mn, Ni, Zn, Cu, Cr and Pb. We did not detect 2 potentially toxic elements, namely Co and Cd. The highest concentration of Fe was detected in the location No. 7 (in the animal and plant material). Other significant concentrations were observed in the location No. 4 (in the bodies of *Chorthippus parallelus*), in the location No. 5b (in the bodies of *Metrioptera roeselii*) and in the location No. 11c (in the bodies of *Metrioptera roeselii*), which had the only Pb concentrations above detection.

| Number | Location     | Species          | Fe   | Mn   | Co   | Ni   | Zn   | Cu   | Cr   | Pb   | Cd   |
|--------|--------------|------------------|------|------|------|------|------|------|------|------|------|
| 1a     | Chemická     | CP               | 0.560| 0.080| <0.050| 0.040| 0.943| 0.192| 0.033| <0.01| <0.003|
| 1b     | Chemická     | MR               | 0.700| 0.110| <0.050| 0.060| 0.764| 0.133| 0.046| <0.01| <0.003|
| 2      | Starobělský potok | CP           | 0.540| 0.130| <0.050| 0.040| 1.110| 0.232| 0.046| <0.01| <0.003|
| 3a     | Kaňovice (no rinse) | CP           | 0.524| 0.101| <0.050| 0.038| 1.200| 0.232| 0.052| <0.01| <0.003|
| 3b     | Kaňovice (rinsed) | CP            | 0.523| 0.075| <0.050| 0.039| 0.947| 0.234| 0.049| <0.01| <0.003|
| 4      | Kaminského | CP               | 0.510| 0.040| <0.050| 0.040| 1.140| 0.223| 0.037| 0.02  | <0.003|
| 5a     | U stavisek  | CP               | 1.710| 0.050| <0.050| 0.030| 0.951| 0.186| 0.037| <0.010| <0.003|
| 5b     | U stavisek  | MR               | 1.110| 0.130| <0.050| 0.040| 0.931| 0.173| 0.051| 0.021 | <0.003|
| 6      | Martinov    | CP               | 0.750| 0.050| <0.050| 0.050| 1.200| 0.237| 0.068| <0.010| <0.003|
| 7      | Na Hrázkách | CP               | 2.880| 0.060| <0.050| 0.040| 1.000| 0.208| 0.048| <0.010| <0.003|
| 8      | Sad Jožky   | CP               | 0.540| 0.050| <0.050| 0.040| 1.370| 0.217| 0.215| <0.010| <0.003|
| 9      | Václavovice | CP               | 0.580| 0.050| <0.050| 0.040| 1.060| 0.232| 0.048| <0.010| <0.003|
| 10     | Nad Doly    | CP               | 1.610| 0.120| <0.050| 0.060| 0.930| 0.184| 0.072| <0.010| <0.003|

**Table 1.** Concentrations of potentially toxic elements of laboratory analysis.
11a Rychvald (no rinse) CP 1.220 0.071 <0.050 0.039 1.090 0.256 0.047 <0.010 <0.003
11b Rychvald (rinsed) CP 1.070 0.060 <0.050 0.036 0.977 0.239 0.044 <0.010 <0.003
11c Rychvald Šídlovecká (no rinse) MR 0.820 0.160 <0.050 0.040 0.764 0.216 0.035 0.093 <0.003
12a Šídlovecká (no rinse) CP 0.648 0.067 <0.050 0.039 1.180 0.225 0.045 <0.010 <0.003
12b Šídlovecká (rinsed) CP 0.467 0.063 <0.050 0.023 0.820 0.171 0.023 <0.010 <0.003
13 Proskovice CP 0.530 0.090 <0.050 0.040 0.972 0.226 0.040 <0.010 <0.003
14 Železná CP 0.510 0.050 <0.050 0.030 1.180 0.229 0.031 <0.010 <0.003
15 Vratimov CP 0.480 0.080 <0.050 0.040 1.140 0.229 0.026 <0.010 <0.003
16 Lesní CP 0.780 0.070 <0.050 0.030 0.875 0.162 0.038 <0.010 <0.003
17 Proskovice Stará ves nad Ondřejnicí CP 0.480 0.160 <0.050 0.030 0.922 0.246 0.034 <0.010 <0.003
18 Ondřejniči Rychvaldská CP 0.400 0.040 <0.050 0.030 0.872 0.204 0.015 <0.010 <0.003
19 R -Na Rychvaldská CP 1.380 0.190 <0.050 0.040 0.819 0.138 0.042 <0.010 <0.003
20 R -Hrázkách TP 2.970 0.270 <0.050 0.040 0.382 0.088 0.035 <0.010 <0.003
21 R - Rychvald TP 0.670 0.190 <0.050 0.030 0.240 0.084 0.020 <0.010 <0.003
22 R - Lesní TP 0.620 0.150 <0.050 0.040 0.241 0.083 0.028 <0.010 <0.003
23 R - Kaňovice TP 0.640 0.130 <0.050 0.040 0.224 0.089 0.021 <0.010 <0.003
24 blind simple - 0.260 <0.010 <0.050 0.020 0.013 0.012 0.023 <0.010 <0.003

CP - Chorthippus parallelus (meadow grasshopper); MR - Metrioptera roeselii (Roesel's bush-cricket); TR – Trifolium pratense (red clover)

4. Discussion
This paper focused on the bioaccumulation of potentially toxic elements in the bodies of Orthoptera insects (Metrioptera roeselii and Chorthippus parallelus). Both of the species are characterized by different food biology. Higher bioaccumulation of Mn, Cu and Pb has been demonstrated in the specimens of Metrioptera roeselii. These potentially toxic elements had higher concentrations than those in Chorthippus parallelus. Higher bioaccumulation of Fe and Zn has been demonstrated in the Chorthippus parallelus species. The dependence of the concentrations of potentially toxic elements in the Orthoptera insects on the distance from the ArcelorMittal a. s. is shown in the Table 2. The dependence of the distance and the concentration of the potentially toxic elements can be inferred from the major axis (S-W).

Table 2. The correlation dependence on the distance and concentration of potentially toxic elements in the orthopteran insects.

| Orientation direct | Fe   | Ni   | Zn   | Cu   | Cr   |
|--------------------|------|------|------|------|------|
| Major axis S-W     | -0.858| -0.650| -0.963| -0.581| -0.714|
| Major axis N-E     | -0.858| 0.115| 0.077| 0.177| 0.035|
| Minor axis N-W     | 0.797| 0.632| -0.549| 0.151| -0.650|
| Minor axis S-E     | -0.642| 0.651| 0.818| 0.796| 0.712|
The Orthoptera insects can be used as an alternative human food source, the results of the laboratory analysis were compared with Decree No. 225/2008 Coll., laying down requirements for food supplements and food enrichment. Of the recommended daily doses given in this Decree, the limit values were exceeded only for the toxic element Cr. Values with a greater percentage than 100 % of the recommended daily dose were operated with a result in this paper. The top Cr abundance was recorded in the location No. 8. This area is located in the minor axis N-W secondary axis, 2.5 km from ArcelorMittal a. s. Verifying the rinsing method of distilled water, which was to avoid external contamination of animal material was one of the partial target. Samples that were labelled as "rinsed" showed generally lower concentrations of potentially toxic elements than those that were not rinsed. The results suggest that the secondary contamination has been demonstrated and that it can be reduced by rinsing still untreated samples in a distilled water bath.

5. Conclusion

Orthoptera insects is a suitable group for the purpose of studying bioaccumulation. Both selected individuals from Caelifera and Ensifera showed different concentrations of selected potentially toxic elements. Rinsing with distilled water, which avoids secondary contamination of samples, appears necessary. The level of contamination was compared with the limits for daily recommended doses according to Decree No. 225/2008 Coll. (Orthoptera insects as an alternative food source). Only Cr limits were exceeded. Significant Cr concentrations were detected in the location No. 8, where the value was exceeded five times.

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