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Urban soil quality assessment using multidisciplinary approach

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1. Introduction

Environmental risk assessment of trace elements (TE) pollution is usually based on the analysis of their soil available contents. At the same time, the chemical analyses do not reveal the complex interactions between the contaminants and soil. Consequently, the Triad approach has been highly recommended and successfully applied for the soil quality assessment, especially in case of trace element contamination. The Triad approach includes three lines of evidence (chemical, ecotoxicological and ecological) provides an accessible way to calculate the integral index of soil quality (Dagnino et al., 2008). This approach was successfully applied to evaluate the soil and sediment quality in different studies (Terekhova et al., 2014; Caeiro et al., 2017); nevertheless, the study for urban soil assessment is scarce. The aim of this study was to assess the soil quality in Bishkek city (Kyrgyzstan) based on the integral approach.

2. Material and Methods

The soil samples were collected from four sites in an urban area at the Bishkek (Kyrgyzstan). These sites are located near the Bishkek fossil station at the distance 10, 50, 150 and 500 m, with the same soil type (anthrosols).

Chemical tests. For trace element analysis in soils, samples were dried, sieved and homogenised. The total Ni2+, Cu2+, Zn2+, As5+, Cd2+, Hg2+, Pb2+ content was determined by inductively coupled plasma mass spectrometry (ICP-M) at the Agilent 7500a, USA. The pH values of the soils were measured using pH meter with glass, ion-selective electrode (HANNA instrument – pH 211).

Ecotoxicology tests. Soil water extraction was carried out with a liquid/solid ratio of 1/4 (100 g of soil in 400 ml of cultural water) at 20 °C in 11 glass bottles for 2 h at a stirring rate of 120 rpm. After decantation for 15 min, the soil suspension phase was filtered (Watman® #2) and stored at 4 °C until analysis. The acute toxicity of samples was evaluated using an endpoint the inhibition of the luminescence naturally emitted by the recombinant Escherichia coli containing lux CDABE genes of Photobacterium leiognathi 54D10. The drop in light emission was measured on luminometer (SKTb Nauka, Russia) after a contact time of 30 minutes with the test sample. Phytotoxicity tests were conducted according to Terekhova et al. (2012) using Sinapis alba (mustard) and Avena sativa (oat) seeds.

Ecological tests. The substrate induced respiration (SIR) was assessed after the addition of glucose (10 mg per g soil) over 24 h. The microbial basal respiration (MBR) was measured in the same manner as the substrate-induced except that glucose had not been added. The mean respiration rate after 117 h was calculated. For CO2 quantification, M3700-400 gas analyzer (Kristall, Russia) was used. A chemical risk index (ChemRI), ecotoxicological risk index (EtoxRI), and ecological risk index (EcoRI) in the range 0-1, were calculated according to Dagnino et al. (2013). The data were analyzed by comparing the results from investigated sites with those from the low-contaminated control site (10 m), and by computing the risk indices for each parameter.

3. Results and Discussion

Tested soils characterized by alkalinity (pH 7.4 – 8.2), and trend to pH increasing was revealed with distance removal from the coal power station. The content of total TE’s in the studied soils, as well the environmental quality standards for selected TE’s in soil, are given in the Table 1.
Table 1. Trace element contamination in anthropos of Bishkek city

<table>
<thead>
<tr>
<th>Distance, m</th>
<th>Trace elements content on soil, mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ni</td>
</tr>
<tr>
<td>0-5 cm</td>
<td></td>
</tr>
<tr>
<td>10¹</td>
<td>19,61</td>
</tr>
<tr>
<td>50</td>
<td>17,97</td>
</tr>
<tr>
<td>150</td>
<td>68,18</td>
</tr>
<tr>
<td>500</td>
<td>21,21</td>
</tr>
<tr>
<td>20-25 cm</td>
<td></td>
</tr>
<tr>
<td>10¹</td>
<td>17,44</td>
</tr>
<tr>
<td>50</td>
<td>22,85</td>
</tr>
<tr>
<td>150</td>
<td>46,69</td>
</tr>
<tr>
<td>500</td>
<td>20,92</td>
</tr>
<tr>
<td>Environmental quality standard for selected element (McDonald et al., 2007)</td>
<td></td>
</tr>
<tr>
<td>TEC**</td>
<td>22,7</td>
</tr>
<tr>
<td>PEC***</td>
<td>48,6</td>
</tr>
</tbody>
</table>

* - sample was chosen as a control according to the lowest TE's content
** TEC - threshold effect contamination, level above which biological effects are possible
***PEC - probable effect contamination, level above which biological effects are probable

We detected potentially hazard Ni, Zn, As, and Pb concentrations in samples collected at 150 and 500 m. Additionally, the calculated values of the chemical risk indexes (ChemRi) for sites 150 and 500 m showed a mildly and high level of contamination. It interesting to note that the soil at 10 m distance from plant was characterized by the lowest level of TE contamination, so this sample was chosen as a reference. Carbon dioxide production in the samples with the glucose additive (SIR) greatly varied across samples collected from the 0-5 cm layer, and had no significant differences for samples collected from the 20-25 cm; the similar trend was observed for basal respiration (BR) activity data. The highest values for SIR and BR detected for site 150 m, and can signalize about stressful soil condition for soil microbial community. Minor inhibitory effects of soil 150 and 500 m on E. coli bioluminescence were detected. At the same time no significant changes on phytotest endpoints were observed. According to this data, the calculated Etore® were low. From the graphs of the ecological state of soils, it can be seen that biological (biindicative) parameters, in particular, the intensity of soil respiration, make the greatest contribution to the assessment of the "intensity" of the ecological state from the spectrum of the indices studied (Figure 1).

Figure 1. Graphical representation of indices of the chemical, toxicological and ecological state of investigated soil samples

4. Conclusion and Recommendations

Integral indices of the ecological state of soils, determined on the basis of the triad approach, were correlated with the categories of quality and degree of loading, similar to that described earlier (Terekhova et al., 2014). Soils from the test plots of Bishkek located at the distance of 150 and 500 m from the coal power station are of the IV quality category with a high degree of load, the ecological state of these soils can be described as...
"severely disturbed". While the soils located at 50 m distance from the plant are of the III quality category with an average load, the ecological state of these soils can be described as "disturbed". We believe that the triad approach to the generalization of data allows us to obtain a complete characterization of the ecological state of soils in comparison with the analysis of individual responses of biota representatives or chemical indices.

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References


