Heavy metals in lignite and soil of Kostolac-Kovin coal basin, eastern Serbia - comparative analysis with selected cities in Serbia, region, Europe and world

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HEAVY METALS IN LIGNITE AND SOIL OF KOSTOLAC-KOVIN COAL BASIN, EASTERN SERBIA - COMPARATIVE ANALYSIS WITH SELECTED CITIES IN SERBIA, REGION, EUROPE AND WORLD

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Abstract:*The Kostolac-Kovin coal basin with an area of 320 km^2, with 5 separate layers of coal and with a total of about 5.7 Bt of geological resources and reserves represents an exceptional potential for coal production in Serbia. The coal resources listed in this way are not fully exploitable, but they represent potential for consideration. In this paper, we deal with the geochemical characteristics of coal seams and perform a comparative analysis of coal affectation on the environment. With 155 analyzes of HM from coal, 45 from ash, 165 from gravel and 30 from soil, we perform analysis of horizontal and vertical distribution of HM and comparative analysis. What interests us as authors and you as readers the most is - whether heavy metals from coal contaminate the accompanying sediments above and around the coal seams layered in the deposit itself. We also provide selected examples of the presence of HM in the soil of numerous European and world cities and regions in order to compare with the concentrations in our lignite. In the following chapters we will deal with this issue.*

Key Words: *lignite, heavy metals, concentrations*

1. GENERAL INFORMATIONS

The coal basin is located in eastern Serbia, between the Velika Morava and Mlava rivers, which flow into the Danube in that area (figure 1 and 2).

It is divided into two parts by the Danube - to the south is the Kostolac Basin, and to the north of the Danube is the Kovin Basin (Figure 2). Geological explorations began in 1941 and continues to this day. In total, 3,200 boreholes were drilled in 80 years, i.e. 275,000 m of drilling (figure 2).

In both basins, the presence of 4 coal seams was registered, which continuously extend under the Danube (Fig. 3 a, b, c). In the part of the unique deposit, on OP Drmno and OP Cirikovac, there is also a 5th coal layer (Fig. 3d) which is of small thickness, is at a great depth and is not balanced. These 4 coal layers (I, Ia, II and III):

1. Parts of I and II layer were in the phase of excavation since early XX century (I and II layer in the underground pits of Stari Kostolac and Ćirikovac, after that in the surface mines of Klenovnik and Ćirikovac, picture 2) and are not being excavated now;

2. Now in the excavation phase are some parts of I, II and III layers (I and II layers in Kovin by underwater exploitation; II and III layers in the Drmno surface mine Figure 2);
3. In the excavation plan are all remaining parts of Ia, I and II layer (Ia, I and II layers at the future surface mine West Kostolac 1; and at the future surface mine Kovin 1)

Figure 1. General geographical position of the Kostolac-Kovin coal basin, red circle - position of the basin

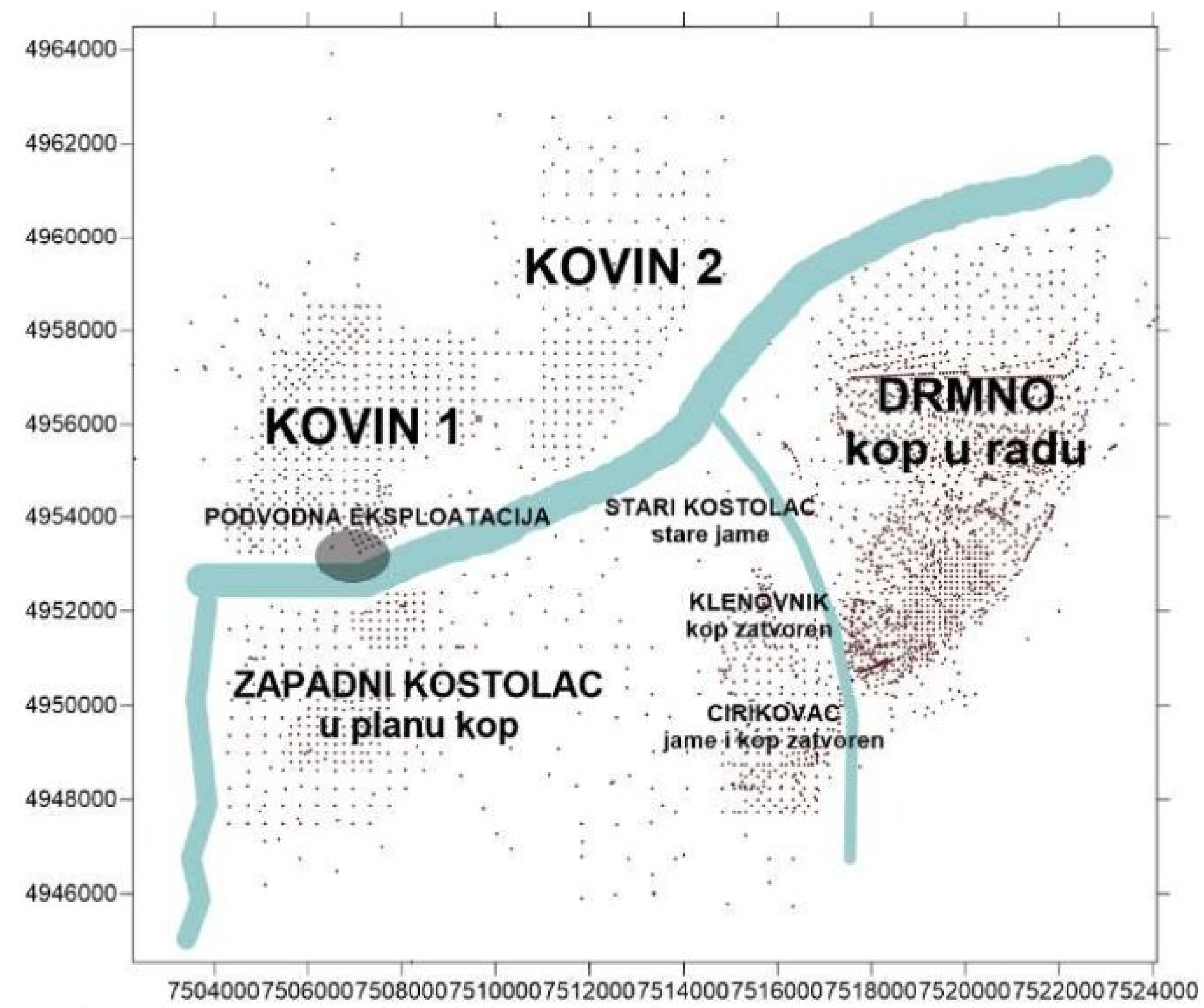


Figure 2. General overview of exploration wells (black dots) for the period 1941-2022. years in the Kostolac-Kovin coal-bearing basin, blue thick line – river Danube, blue thin line left – river Velika Morava, blue thin line center – river Mlava, gray circle - underwater mining of Kovin lignite

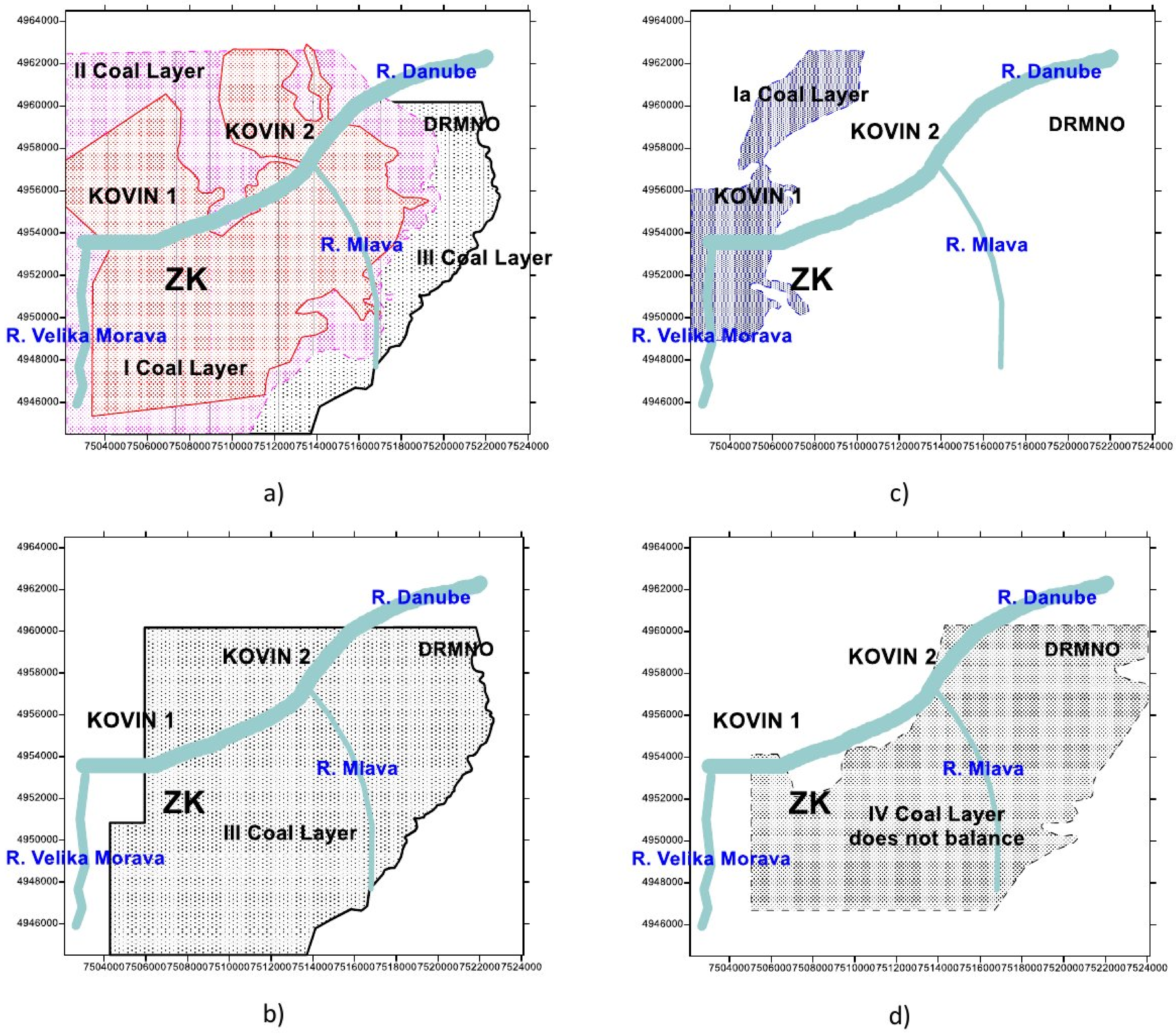


Figure 3. General view of the spatial distribution of 5 separate coal seams in the Kostolac-Kovin coal bearing basin - a) I (red dots) and II (pink dots) coal seams; b) III (black dots) coal layer; c) Ia coal layer; d) IV coal layer, not balanced

The mentioned coal layers are generally not definitively contoured either laterally or in depth, but there is a potential for their further research outside the existing exploration fields. The general calculation of coal resources for all 5 coal seams yielded about 5.75 B t of coal.

2. GEOCHEMISTRY OF LIGNITE, ACCOMPANYING SEDIMENTS AND SOIL IN THE BASIN AREA

Numerous analyzes were taken to determine the quality of lignite, as well as numerous others for geotechnical and hydrogeological purposes. In the last ten years, special attention has been paid to the ecological characteristics of lignite, and the contents of HM have also been determined. Apart from coal, samples were also taken from all sediments in the horizontal and vertical profile of the deposit; as well as from the soil above the Drmno deposit and from gravel from the wider area.

HORIZONTAL DISTRIBUTION

For the laboratory analysis of HM, samples were taken separately from the I, II and III coal layers; as well as from the ashes after burning the same samples. A total of 155 samples were taken from coal and 45 from ash. A total of 22 chemical elements were analyzed. Here is an overview of three. It can be concluded that there is a certain lateral zonation of the distribution of Zn, Cu and Pb (ppm) in such a way that in the area of the Drmno deposits there are lower, and in the area of West Kostolac and Kovin, elevated HM values (Figure 4).

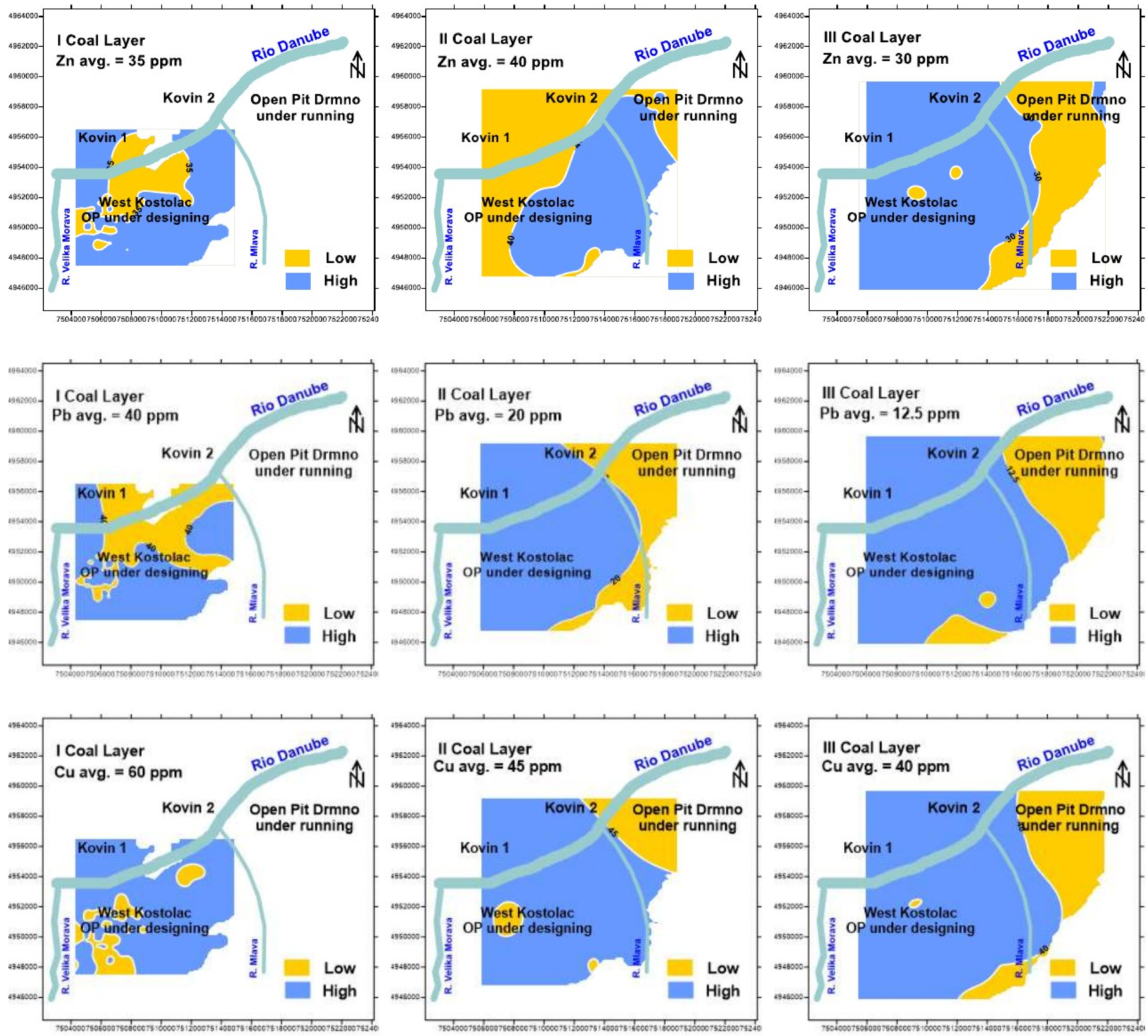


Figure 4. General view of the horizontal distribution of Zn, Cu and Pb in the I, II and III coal seams of the Kostolac-Kovin coal-bearing basin; blue – increased values, yellow – decreased values

VERTICAL DISTRIBUTION

A large number of individual samples were taken in the vertical profile and 17 lithological members were laboratory tested for 22 chemical elements, including the surface humus layer, gravel, coal layers and all types of clay and sand. A presentation of the vertical distribution of Zn, Pb, Cu is given (Figure 5).

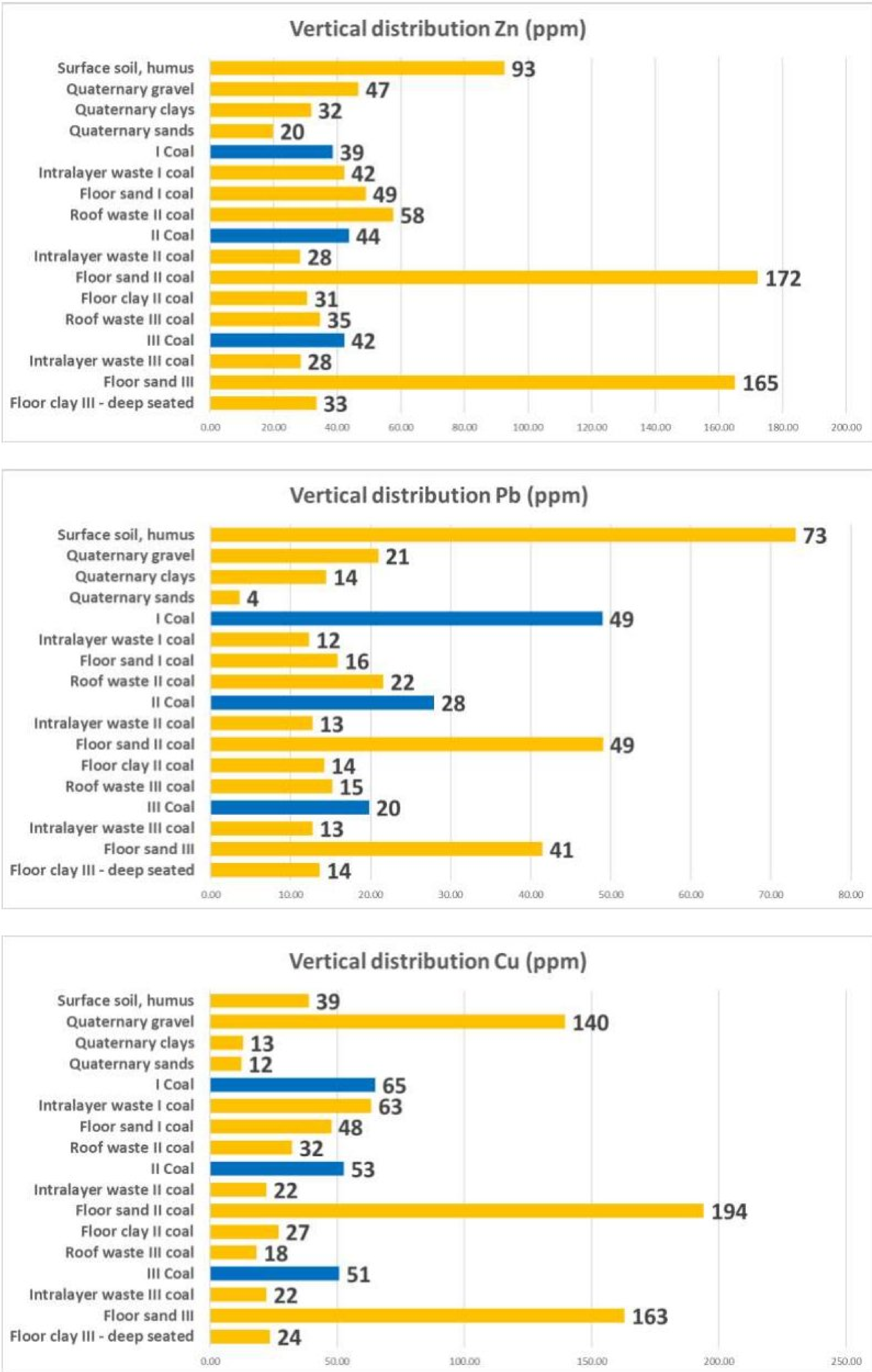


Figure 5. General view of the vertical distribution of Zn, Pb and Cu in the lithological suite of the Kostolac-Kovin coal-bearing basin; blue - coal, yellow – waste

The conclusion is that the contents of Zn, Pb and Cu in coal are generally significantly lower than those registered in the sediments of the tailings at all levels, starting from the surface of the terrain to those in the deepest levels. This speaks in favor of the fact that the geochemical conditions during deposition, and subsequently diagenesis of coal, were different for coal compared to sediments. That is, the plant matter that formed the coal layers did not contain increased concentrations of HM, and this is reflected in their contents in the coal. Also, in the process of coal diagenesis there was no yield of HM in coals.

The general conclusion is that the coals with their concentrations of Zn, Pb and Cu do not pollute the sediments below or above the coal beds, and they also do not pollute the gravel or the productive humus layer of the soil that are at the top of the sedimentation sequence of this area.

3. COMPARATIVE PRESENTATION OF THE CONTENT OF HM IN THE LIGNITE OF THE BASIN AND SELECTED EXAMPLES - SERBIA, REGION, EUROPE AND THE WORLD

For easier understanding of the content of these HM, we performed a comparative analysis of the content of HM in the lignite's of the Kostolac - Kovin basin with selected examples from numerous cities in Serbia, the Region, Europe and the World.

3a. SOIL OF THE URBAN, RECREATIONAL AND INDUSTRIAL ZONES – SELECTED CITIES OF SERBIA

It is often considered that coals are extremely "toxic" and that their burning leads to significant soil pollution throughout Serbia and the world. However, measured data on HM content in the soil of cities throughout Serbia show a completely different picture. Namely, the contents of Zn, Pb and Cu are significantly higher in the urban, recreational and industrial soil of cities throughout Serbia than in the coals of Kostolac (Figure 6).

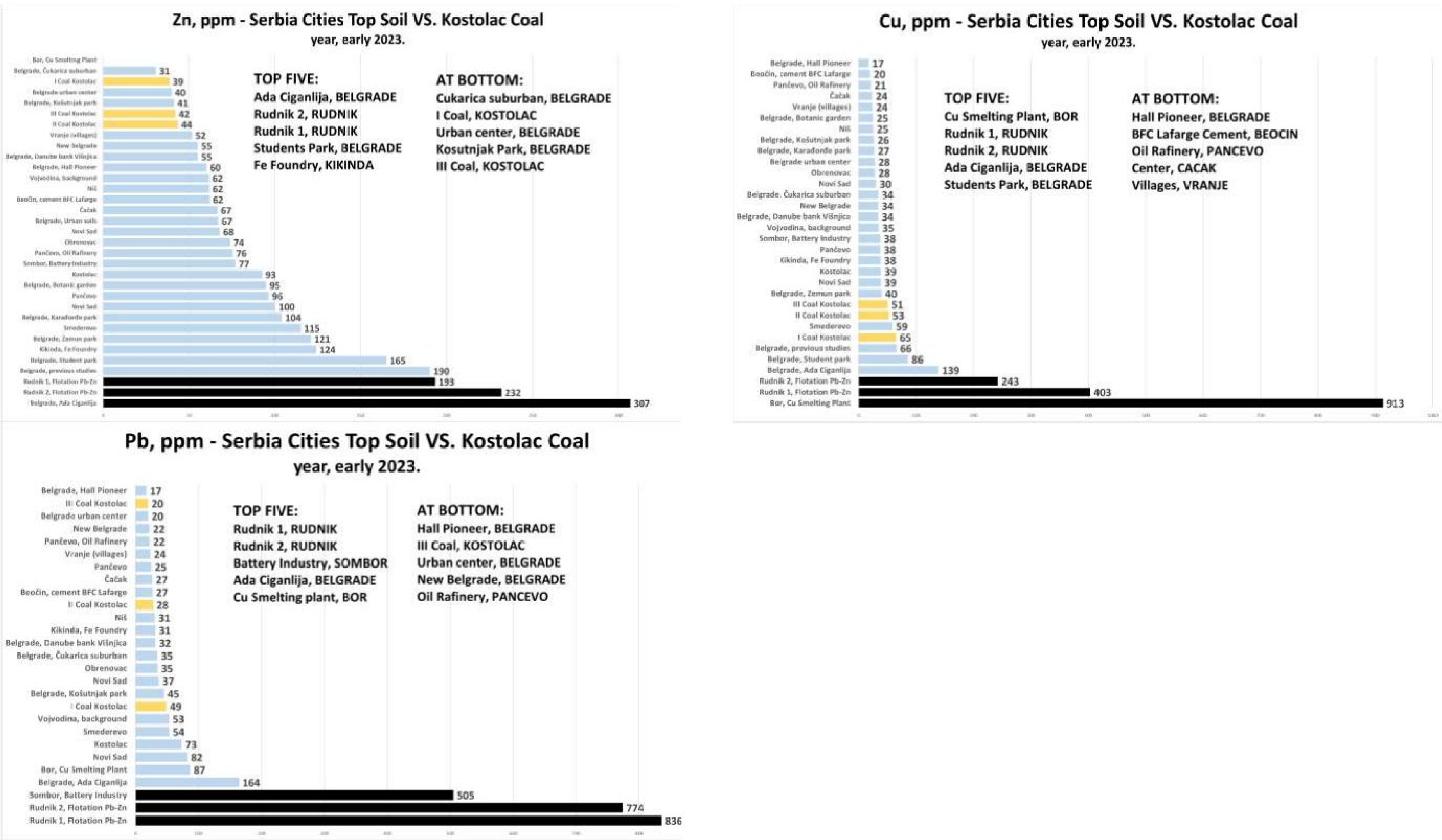


Figure 6. Content of Zn, Pb and Cu in urban, recreational and industrial top soil in Serbian cities; light blue - medium values in selected Serbian soils, yellow - I, II and III Kostolac coal, black - the most polluted soils

For example, from Figure 6, it can be seen that the top soil in the popular recreational area of Ada Cignalija in Belgrade contains significantly higher concentrations of Zn, Pb, Cu than the rest of the examined zones, as well as the coal of the Kostolac-Kovin basin. A typical example is Zn, which shows even extremely low concentrations compared to other locations on the diagram.

3b. SOIL OF THE URBAN AND RECREATIONAL ZONES – SELECTED CITIES OF REGION

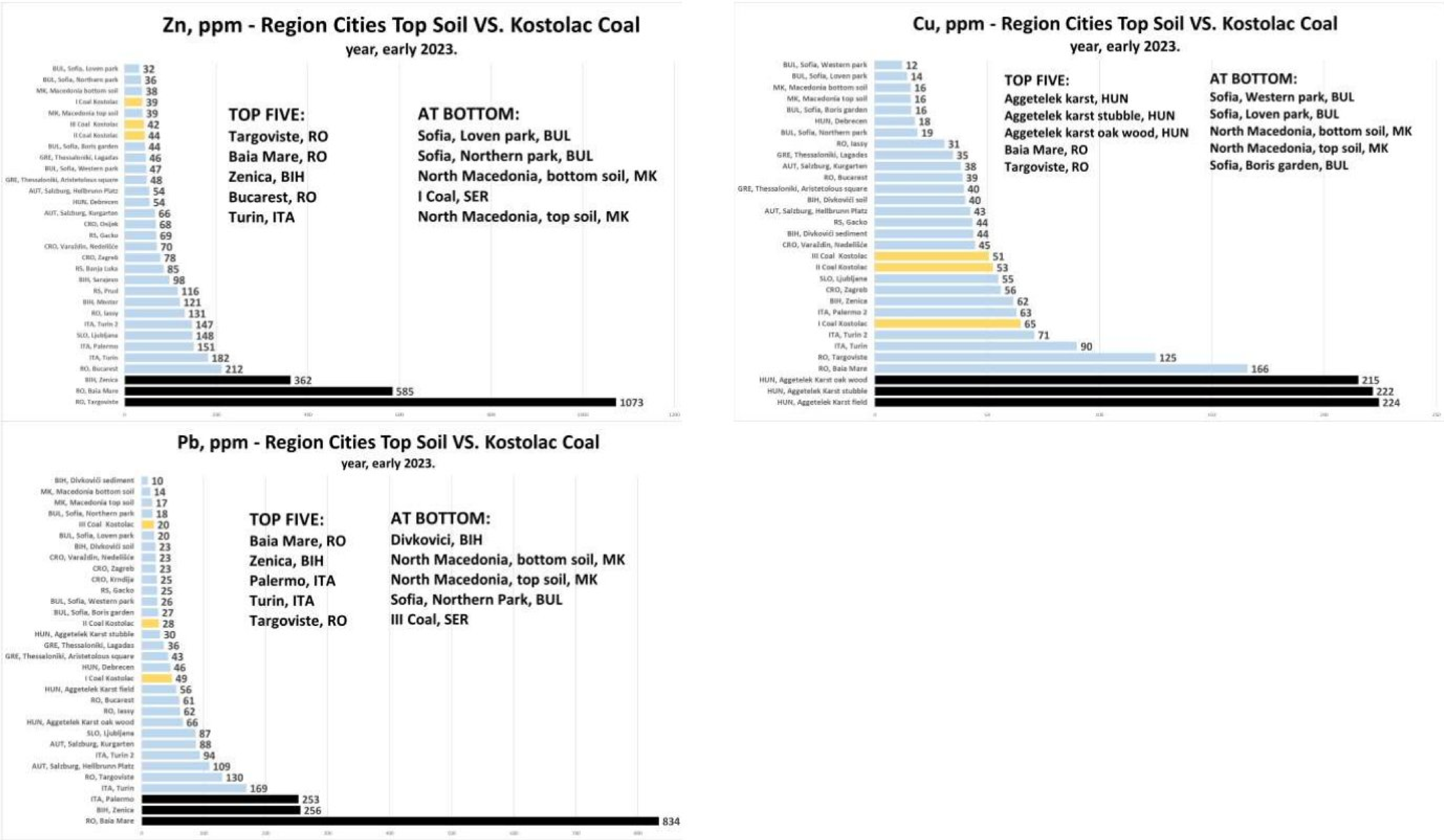
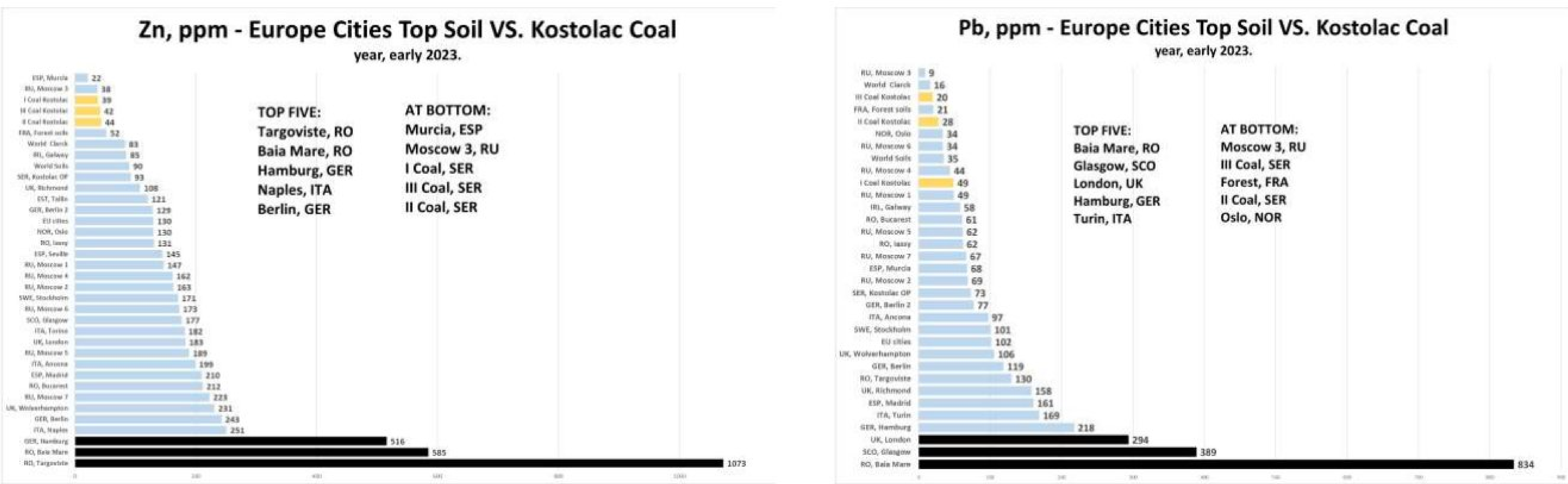


Figure 7. Presentation of the content of Zn, Pb and Cu in the urban, recreational and industrial top soil in the cities of the region; yellow - I, II and III Kostolac coal, black - the most polluted soil

Figure 7 shows that the contents of Zn, Pb, Cu in the top soil in the cities of the region behave almost identically as in the previous comparison with the soil of Serbia. Again, there are marked increases in content in the marked locations of the region.

3c. SOIL OF THE URBAN AND RECREATIONAL ZONES – SELECTED CITIES OF EUROPE



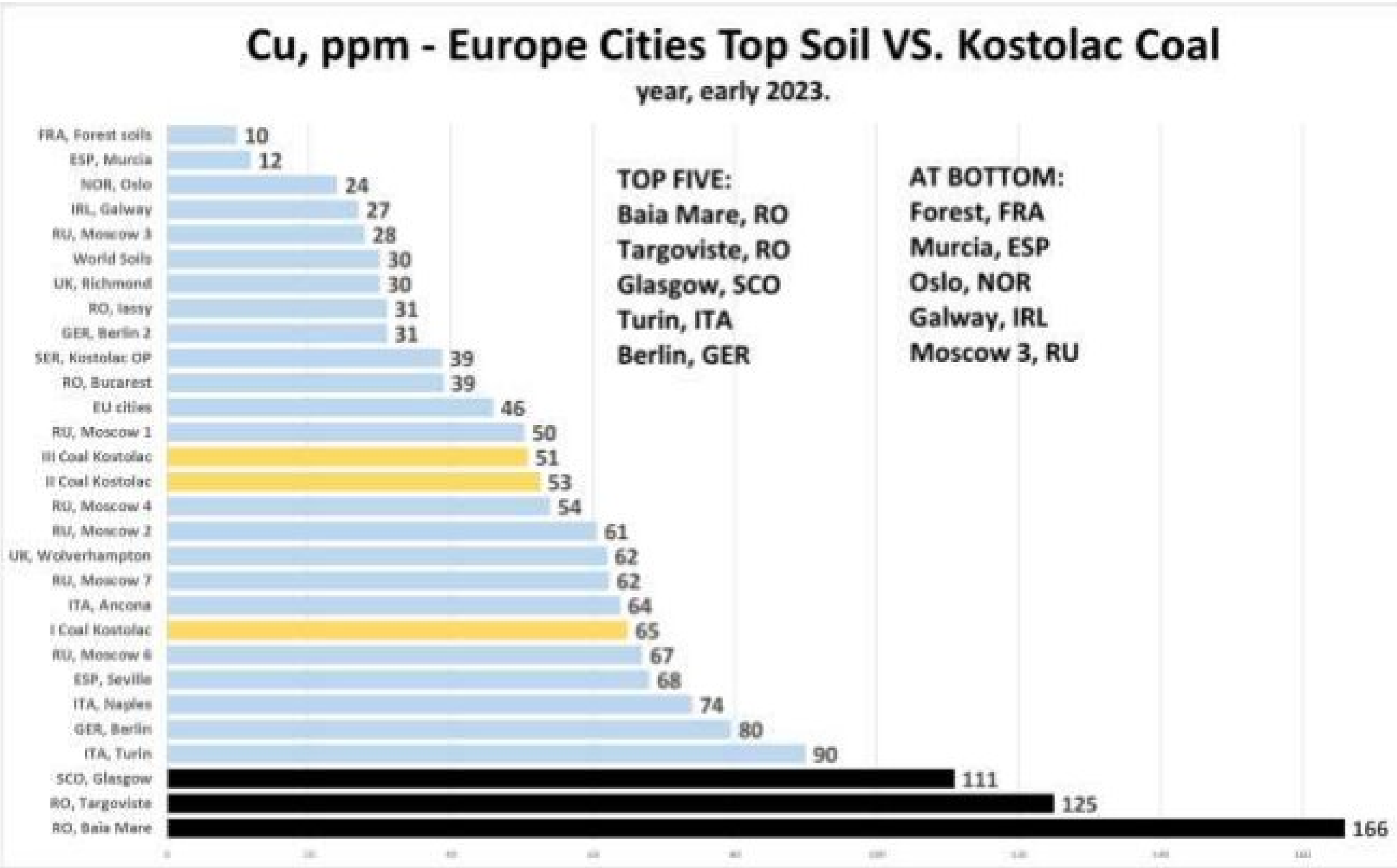


Figure 8. Presentation of the content of Zn, Pb and Cu in the urban and recreational top soil in the cities of the Europe; yellow - I, II and III Kostolac coal, black - the most polluted soil

Figure 8 shows that the contents of Zn, Pb, Cu in the top soil of the cities in the Europe behave almost identically as in the previous comparison with the soil of Serbia and region. Again, there are marked increases in content in the marked locations of the Europe.

3d. SOIL OF THE URBAN AND RECREATIONAL ZONES – SELECTED CITIES WORLDWIDE

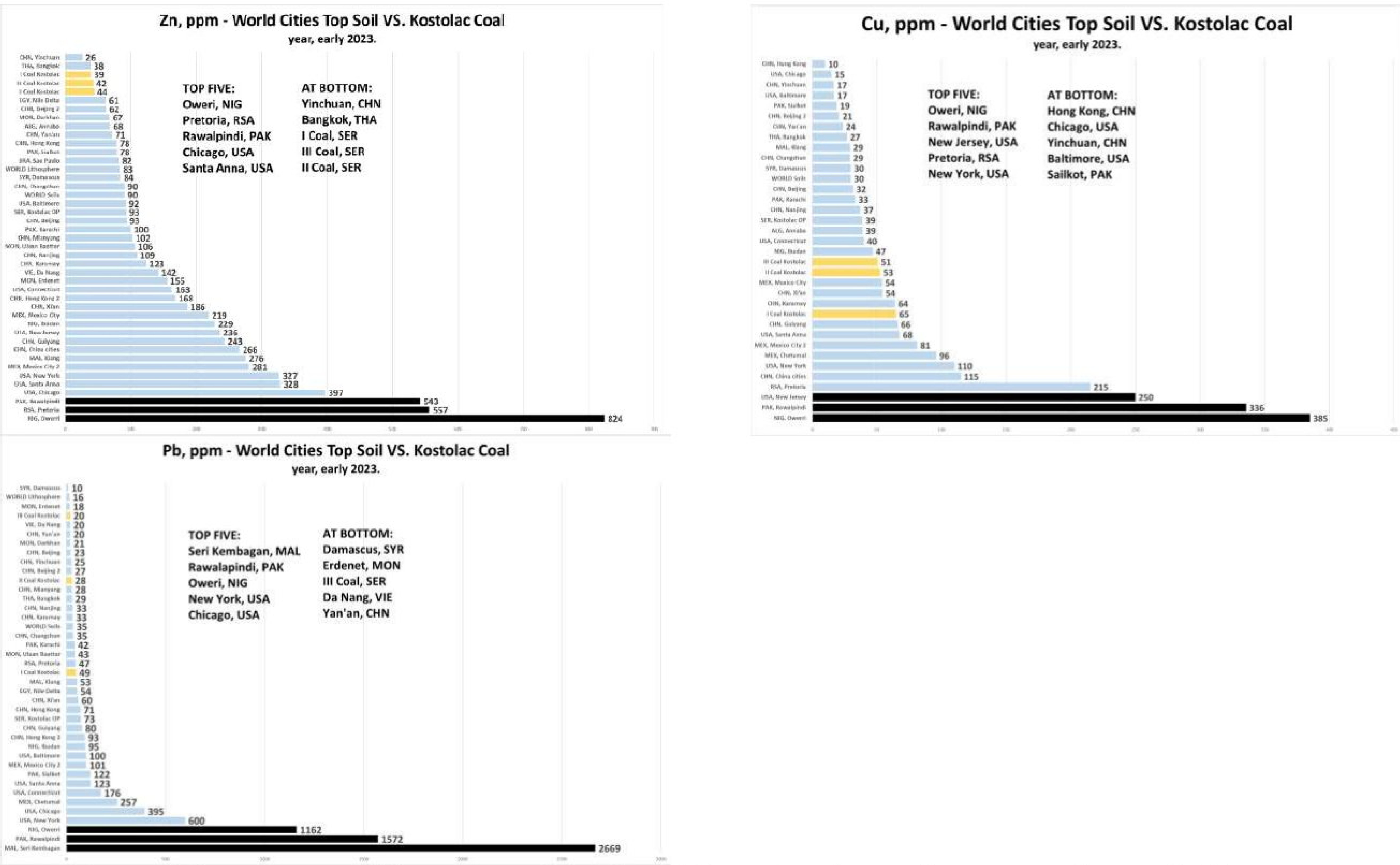


Figure 9. Presentation of the content of Zn, Pb and Cu in the urban and recreational top soil of the cities Worldwide; yellow - I, II and III Kostolac coal, black - the most polluted soil

Figure 9 shows that the contents of Zn, Pb, Cu in the top soil of the cities worldwide behave almost identically as in the previous comparison with the soil of Serbia, Region and Europe. Again, there are marked increases in content in the marked locations of the World.

4. CONCLUSION

The lignite of the Kostolac-Kovin Basin generally has low concentrations of heavy metals, compared to worldwide cities top soils. In this work, special attention is paid to the content of Cu, Pb and Zn and their horizontal and vertical distribution. Also, a comparative analysis was performed with top soil in a large number of cities in Serbia, Region, Europe and World. Based on this, it can be concluded that the concentrations of the mentioned HM are significantly higher in the top soils of urban, recreational and industrial zones of many cities in Serbia, Region, Europe and World, which are significantly far from this deposit.

So, we conclude - the coal from the deposit itself does not in any way pollute the surrounding soil that is below or above the deposit. The contents of heavy metals in the top soil of the mentioned cities in Serbia, Region, Europe and World are mainly a consequence of the geological composition and geochemical background of that region, as well as anthropogenic/industrial influence.

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