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**DELIMITATION OF ZINC AND COPPER
CONCENTRATION IN BOCHNIA SOIL****DELIMITACJA KONCENTRACJI CYNKU I MIEDZI
W GLEBACH BOCHNI**

Summary: Spatial differentiation of Cu against Zn content in the near-surface soil level in an urbanized area was presented. Delimitation of characteristic areas of tested elements was performed. Conducted research revealed changing differentiation of Zn and Cu content in the soil depending on emitters, area development and environment characteristics. Changing content of both elements along the distance from the road was also compared. No crucial connection was pointed regarding the content of tested elements in all samples taken in the vicinity of roads. High correlation between Zn and Cu content was noted in case of samples taken on the same side of the road, though. In 85 % of samples located both north and south of Bochnia ring road and Łapczyca E-4 road Cu content is higher than Zn content. However, in places situated at the similar distance from the road, on a flat area and in a road pit near a steep ascending road at Wiśnicka street, Zn content is higher than Cu content. The highest average content was measured for source segment of Babica through which the ring road goes. Such areas are characterized with increased Zn content and higher correlation between Zn and Cu. Definitely the lowest condensation of those elements was measured among compact building development. This research revealed further need to investigate change of concentration of those elements in the area depending on the characteristics of the environment.

Keywords: abiotic environment, concentration Zn, Cu, soil, urbanized area

The purpose of this work is an evaluation of spatial diversification of Cu *versus* Zn content in an urbanized area on the example of Bochnia and its closest surroundings. The Zn and Cu content higher than average was observed in the town centres as well as along communication roads [1]. Some researchers say that higher Cu content reaches to 5 m and for Zn even to 100 m away from a road edge [2]. It depends on wind directions and traffic intensity [3]. The highest Zn content is stated mainly the nearest the road while the Cu content is different [4]. There are different opinions of researchers about decreasing of the Cu soil pollution along with the distance from town centres [5]. In Bochnia, a relatively higher Zn and Cu content was also measured near busy roads. But those concentrations do not exceed allowed norms [6].

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Method

The content of both elements was measured in 77 samples taken from the depth of about 15 cm [8]. The analysis was performed by the atomic absorption method AAS with the use of Elmer Perkins 2001 spectrometer. This spectrometer estimated the Zn and Cu content in a sample ground to the particle size of 0.2 mm. Measured quantities refer to overall content.

Results and discussion

Both north of road E-4 and in the surroundings of Bochnia ring road Zn content decreases as one gets away from the roads (from 7.6 ppm), to increase 60 m away up to level of 9.6 ppm, especially close to barriers and obstacles of different sort, for example 10.6 ppm 250 m away at a building development near the Southern slope of the Uzbornia ridge. A similar regularity affects also Cu (Fig. 1). The content of this element is relatively higher, though. It changes from 41.1 ppm 3 m away from the road to 8.0 ppm 100 m away and increases to 21.5 ppm 160 away from the ring road. Thus, the highest element content in the soil is right at the road. The lowest content of both elements was noted 500 m away the road on the Uzbornia ridge, behind the building development barrier (Zn - 2.1 ppm, Cu - 2.4 ppm). A similar regularity was noted behind Łapczyca building development in about 100 m distance north of E-4 (Cu - 8.0 ppm and Zn - 4.9 ppm). A decrease of Zn and Cu content with the distance points to another correspondence depending on the area. On both sides of a high ring road embankment, soil contains a smaller amount of the analysed elements. The area situated on the height of the embankment, on the slope of the valley and bordered with a building development barrier from the north, 250 m away from the ring road, shows a pollution increase (Cu - 21.2 ppm, Zn - 10.6 ppm).

The highest Zn content (28.2 ppm) was noted south of the road, at the ascending section of Bochnia ring road, near a band made of galvanized sheet. A high content of this element in a similar place is confirmed by a sample from Łapczyca taken on an ascending road, on the right side. As one gets away south of the ring road (E-4) in Bochnia, the Zn content becomes lower and lower. 30 m away from the road its concentration significantly drops to 7.6 ppm. A similar content is also found 250 m away from the ring road (7.8 ppm). The Cu concentration drops slowly with the distance from this road from 16.4 ppm to 14.4 ppm 30 meters away (Fig. 1).

The cause of such a changing Zn and Cu content in the soil is the embankment and open area surrounding the ring road, well aerated from the south west. A different distribution of Zn and Cu content was found in Łapczyca south of E-4 as one gets away from the road. The batter is not high from the southern side, but 100 m away there is a forest line situated on the left slope of the valley. The Cu content increases with the distance from concave batter bend and is the highest 45 m away from the road being 20.6 ppm. The concentration remains on this level also close to the forest - 16.2 ppm (90 m from the road). A sudden drop of the content of both elements is noted on the

edge of the forest, in the case of Cu it drops to 1.6 ppm (Fig. 1). The decisive factor is the forest barrier and soil properties.

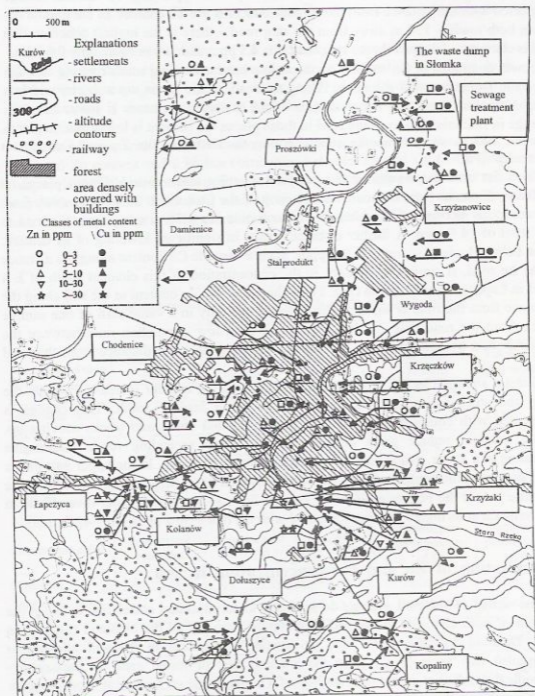


Fig. 1. Spatial distribution of Cu and Zn in soil in soil classes of content in Bochnia and vicinity

On an open space between the ring road ascending section to Kolanów and Kolanowska street, the Cu concentration in the soil decreases away from the road (24,7 ppm) with heavy traffic – ascending ring road section – to less busy Kolanowska street situated on a gentle slope, about 250 m north away to 8.6 ppm (Fig. 1). Another change connected with the distance from those roads concerns the Zn content. In the middle between both roads – 130 m away from the ring road – there is the highest concentration of this element – 7.1 ppm. At the ring road it is 4.5 ppm and 200 m away only 0.6 ppm.

Lower quantities of Zn and Cu occur on less busy ascending roads running through forests in Dołuszyce and Kopaliny. Along the road, in the forest, on a shorter and less steep ascending road, the concentration of the analysed elements is lower than the average in Bochnia. Closer to the road in those places the content is lower than in places situated 100 m away from the road. Along the distance, the Zn and Cu content decreases (Fig. 1).

In a flat area the results of the analyzed samples taken from different places, at different distances from the road, show a drop of the Cu content 20 to 40 m away from the road. An increase of this element concentration starts 50 m away from the road to the level of 14.9 ppm. A further distance results in significant lowering of its content, even below Bochnia average, to 2.3 ppm. Such a variable Cu content along the distance from the road, is similar to changes in the concentration of this element south of E-4 road in Łapczyce and Bochnia (Fig. 1). A change of the Zn content in the soil along the distance from the road is similar. The difference is only in a value shift of one sample taken from the road (Fig. 1). It is confirmed by a low correlation ratio between the concentration of both elements in samples taken at the same distance from the road (0.15).

Special attention needs to be paid to the Zn and Cu content increase upwards the long and steep ascending road on Wiśnicka street leading south. This change is connected with combustion of fuel by heavily loaded buses and trucks moving up. Those vehicles reduce gears during long and steep ascending roads. An engine operating at a lower torque results in increased fume emission. In the upper part of the ascending road the content of both elements is several times higher compared with more a gentle part at the beginning (Cu – 8.7 ppm; Zn – 31.4 ppm). Smaller diversification concerns Zn at its higher content compared with Cu (Cu – 30.5 ppm; Zn – 42.5 ppm).

Delimitation of Zn and Cu concentration in soil

The results of obtained analysis do not point to an important correlation between the content of both elements in the soil. Correlation ratio for all the obtained results was 0.31. Detailed analysis of Cu and Zn spatial distribution in the soil allowed to distinguish two areas (Fig. 1). In the western part of tested area: in Łapczyce – Niepodległości district, in the surroundings of a boiler-house on Kampi, at Wodociągowa street, in the vicinity and inside Niepołomice forest close to Damianice, near water spillage from sedimentation tanks and on both sides of the ring road (concerns 30 samples) – Cu content was higher than Zn content. Zinc was dominant in the eastern part of the tested area (41 samples) beyond a belt along the ring road. In the western

part the Cu content is about three times higher than in the eastern part. The arithmetic average is correspondingly 15.2 ppm and 5.2 ppm (Table 1). Slightly smaller differences between those areas concern Zn. In the eastern part the average content of this element is 8.3 ppm, in the western part it is 5.5 ppm. Those areas are clearly differentiated by the correlation ratio between Zn and Cu concentration in the analysed areas (Table 1).

High correlation between Cu and Zn concentration concerns the eastern part – 0.882 (Table 1). In that area arithmetic average of Zn content is relatively high. Small correlation occurs in areas where Cu dominates (Fig. 1). In the western part increased human activity is observed as there is high fuel combustion in car engines. Those areas are well aerated.

Enclosed areas with limited aeration, situated along communication routes, show an increased Zn content and a higher correlation between Zn and Cu. An example is the compact building development in Bochnia centre and the high slopes of the road cut-out near Wiśnicka street. Excluding road vicinity, analysis from the calculations lowers both the average value and the correlation ratio between both elements in the city centre (Table 1).

Table 1

Mutual correlation and mean contents of Zn and Cu in soil
in aerial divisions of Bochnia

Geographical units	Sandomierz Basin		Okocim elevation		Babica stream headwaters		Brzesko foothills		Town centre, highly urbanised	
	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu
Arithmetic mean [ppm]	3.9	4.2	8.9	6.4	14.1	18.7	3.4	1.1	12.4	3.8
Correlation coefficient	0.021		0.446		0.067		0.75		0.985	
Number of samples	22		22		14		7		13	
Territorial units	Town centre, roadsides		Samples with pH = 5–6.7		Samples with pH = 6.7–7.4		Eastern part, predomination of Zn		Western part, predomination of Cu	
	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu
Arithmetic mean in ppm	2.7	0.4	6.1	7.0	8.1	9.1	8.3	5.2	5.5	15.2
Correlation coefficient	0.319		0.358		0.369		0.882		0.231	
Number of samples	9		28		45		46		30	

The highest average Zn content – 14.1 ppm and Cu – 18.7 ppm is observed in the source segment of Babica through which the ring road goes. This area is well aerated. No essential correlation between Zn and Cu concentration was noted here (0.07).

Small differences in the average content of the elements tested was calculated depending on soil pH reaction (Table 1). Zn and Cu concentrations change slightly depending on the reaction by about 2 ppm of average content. At higher reaction levels it is higher for Cu. There is also no dependence between Cu and Zn content, independently of pH reaction level.

The lowest values, especially Cu - 0.4 ppm (Zn - 2.7 ppm), were measured in the town center, among compact building developments, beyond a belt along the roads (Table 1).

There is also no important connection between the content of those two elements in 23 samples taken near the roads (correlation coefficient 0.161). An important change of correlation concerns the concentration of those elements near the road where their highest content was measured: over 15 ppm Zn and 8 ppm Cu (Fig. 1).

High correlation between Zn and Cu content in the soil was noted on the same side of the road. Defining a dependence in this case was based on a small amount of data. A low correlation coefficient was calculated for all samples from both sides of the road. Correlation coefficient calculated separately for samples from the opposite sides of the road are positive on one side, negative on the other. In Łapczyca, quite a high correlation was noted separately for each side of the road. North of E-4 it was 0.964, south it was 0.985. A high positive correlation also concerns 7 samples taken from various places at the roads in a similar distance from the roadway. Lower correlation ratio was noted for samples taken between the ring road in Kolanów and Kolanowska street - 0.62 and south of the ring road between viaducts from the eastern side - 0.6. The research area in Kolanów is situated between the ring road and a parallel coefficient leading to the town center. The distance between those two roads is approximately 250 m. This is not a developed area. Fuel combustion due to cars on both roads has an influence on both elements content in the soil.

At the ring road a high Zn content is connected to a high degree with a band made of galvanized sheet. No crucial correlation between the content of both elements results also from thorough aeration of highly situated embankment. This problem requires further detailed research. Samples taken on the northern side of Bochnia ring road show a negative correlation for Zn - Cu the coefficient is 0.87.

Conclusion

Combustion of liquid fuel by car engines is a threat for the environment. The size of this threat depends not only on the volume of the emission of an individual element, but also on the characteristics of the environment. In 85 % of samples taken both north and south of the ring road in Bochnia and E-4 road in Łapczyca, Cu content is higher than Zn content. At places situated at a similar distance from the road in a flat area and in a road pit near a steep road ascent on Wiśnicka street, Zn content is higher than that of Cu. The obtained results point to the fact that Zn accumulation in the soil is favored by poor aeration. This research points to the need for further investigation of the change of concentration of various elements in the area depending on the characteristics of the environment.

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DELIMITACJA KONCENTRACJI CYNKU I MIEDZI W GLEBACH BOCHNI

Streszczenie

Przedstawiono zróznicowanie przestrzenne zawartości Cu względem Zn w poziomie przypowierzchniowym gleby w obszarze zurbanizowanym. Dokonano delimitacji obszarów o charakterystycznej koncentracji badanych pierwiastków. Przeprowadzone badania wykazały odmienne zróznicowanie zawartości Zn i Cu w glebie w zależności od emitatorów, morfologii i zagospodarowania terenu. Porównano także zmienność zawartości obu pierwiastków wraz z odległością od dróg. Największą zawartość średnią: Zn – 14.1 ppm i Cu – 18.7 ppm obserwuje się w źródłowym odcinku Babicy, przez który biegnie obwodnica. Obszary zamknięte o ograniczonym przewietrzaniu, położone wzdłuż szlaków komunikacyjnych, wykazują zwiększoną zawartość Zn i większą korelację między Zn i Cu. Zdecydowanie najmniejsze wartości tych pierwiastków pomierzono w centrum miasta, wśród zwartej zabudowy, poza pasem wzdłuż dróg. Nie wykazano istotnego związku między zawartością badanych pierwiastków we wszystkich próbkach pobranych w pobliżu dróg. Natomiast dużą korelację między zawartością Zn i Cu w glebie stwierdzono dla próbek pobranych po tej samej stronie drogi. W 85 % próbek zlokalizowanych zarówno na północ, jak i na południe od obwodnicy w Bochni i E-4 w Łapczycu zawartość Cu jest większa niż Zn. Natomiast w miejscach położonych w podobnej odległości od jezdni, na terenie płaskim oraz we wkopie drogowym przy stromym podejściu na ul. Wiśnickiej większa jest zawartość Zn niż Cu. Badania te wykazały potrzebę badania zmienności koncentracji w terenie różnych pierwiastków w zależności od właściwości środowiska.

Słowa kluczowe: środowisko abiotyczne, koncentracja Zn, Cu, gleba, obszary zurbanizowane