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Research Article

Content of heavy metals in Carpathian soils (Poland)

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Abstract

The article addresses determining the concentration of six chemical elements: Cd, Cr, Cu, Ni, Pb, and Zn in the soils of the southern slope of the Jaworzyna Krynicka mountain in the Beskid Mountains. The research consisted of determining the diversity of metal content in soil samples taken at different altitudes (500, 600, 700, 800, 900, 1000, and 1100 m MSL). The test results indicated low soil contamination in the selected area, particularly for the altitudes of 500 and 900 m MSL. For these altitudes, the content of Cd, Cr, Cu, Ni, Pb, and Zn was similar to the concentration of these metals in uncontaminated soils. In the conducted research, very low Cd content was found for all absolute altitudes. The chemical element of metal whose content in the soils under study was the highest and exceeded natural values was Zn. All tested metals showed a common trend of increasing content in the soils up to 800 m MSL.

Introduction

Chemical elements of heavy metals are widespread in the natural environment. They pose a great threat to living organisms when introduced into the environment in excessive quantities [1-3]. Atmospheric dust containing heavy metals enters the soil. The source of metals in the soil is the bedrock and atmospheric pollution caused by industrial emissions and vehicle traffic. The natural content of heavy metals in soil is closely related to the type and kind of soil [3]. The exacerbation of metal deposition depends on the size of emissions, physical properties of dust, and weather conditions.

Metals with a high environmental risk were selected for the study. When these metals are introduced into the soil they accumulate and remain in the soil for a long period [4,5].

Due to the prolonged atmospheric dust, low pressure, and strong wind, heavy metals are displaced over considerable distances from emission sources [6,7]. This occurrence is observed, in particular, in mountainous areas, where plants and soil are contaminated with heavy metals despite the absence of sources of emissions of these metals in the immediate vicinity [8,9].

For research to observe the impact of long-range emissions on the size of the accumulation of heavy metals in soil, a mountainous area was selected [10]. Under the influence of such emissions, even naturally important areas such as the Beskid Mountains, are exposed to the effects of human activities (industry, traffic emissions, and nearby coal-fired towns). The spread of pollutants is influenced by altitude above sea level, as well as proximity to a major mountain ridge. The characteristic conditions of mountainous areas increase wind speeds, which may result in higher accumulations of metals in the soils of areas located at the highest altitudes.

It is an environmentally valuable area, located within the boundaries of the Poprad Landscape Park [11]. Many tourists and guests visit the site due to the Krynica-Zdrój and Muszyna sanatoriums and rest houses located there [12,13]. These towns are famous health resorts in Poland [14,15]. This region is also a popular Polish ski resort [16,17] and tourist area [18,19].

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Materials and MethodsThe subject of the research was the area of the Carpathian Mountains in the Beskid Sądecki, Poland. Samples (10 samples per testing ground) were taken from seven testing grounds (A, B, C, D, E, F, and G) at altitudes of 1100, 1000, 900, 800, 700, 600, and 500 m MSL located in the area with southern exposure (Figure 1). In the study area there are light and medium loams, sometimes dusty, with skeletons of various sizes [20].

Climatic conditions in the mountainous area of the Beskids depend on many factors, including altitude above sea level, exposure, and terrain. The conditions prevailing there correspond to the habitat types of forests, in particular to the growth and development of mountain forests and mountain mixed forests. In the case of advective weather, situations with air inflow from the west (18.8%) as well as from the south and northwest prevailed, on average, in 11.0% of all cases [21]. Samples were taken in September 2022. The average temperature during sampling was 14 °C and no precipitation was recorded.

The laboratory work was carried out following the methodology used to collect and prepare samples for chemical analyses [22,23]. The content of heavy metal elements was determined by inductively coupled plasma mass spectrometry (ICP-MS) in the Bureau Veritas laboratory.

Results and discussion

The results of the research indicate that the concentrations of all tested metals, except for lead, increase to an altitude of 800 m MSL. Only the concentration of lead in the soil increases with the increase in altitude (Table 1). Perhaps such metal content in the soil is influenced by its pH and land cover. On the highest altitude testing grounds, there are beech forest habitats, while in the testing grounds located at altitudes of 800 - 700 m MSL, beech-spruce-pine mixed stands predominate, in the habitat of the mountain forest. Testing grounds at altitudes of 600 and 500 m MSL are grasslands, pastures, and arable fields. The value of soil reaction for individual sampling sites varied from very acidic for the highest areas: 1100-900 m MSL (pH in H_2O: 4.0-4.3), through acidic for areas from 800 - 700 m MSL (pH in H_2O: 5.5-6.3), to neutral or slightly acidic pH for areas at 600-500 m MSL (pH in H_2O: 6.2-7.2).

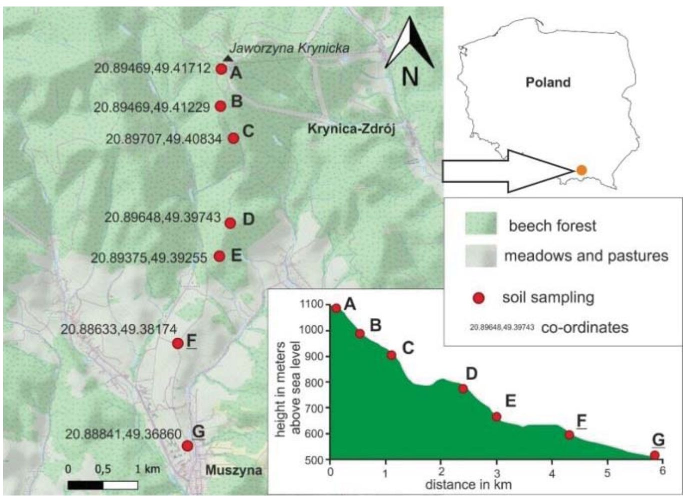

Figure 1: Location of testing grounds.

Table 1: Metal contents in the soil.

Altitude [m MSL]	Average metal content [mg/kg], n = 10 for each altitude					
	Cd	Cr	Cu	Ni	Pb	Zn
500	0.29	16.23	8.27	12.48	17.78	55.07
600	0.43	27.35	24.05	28.50	24.28	74.78
700	0.52	36.76	35.81	44.21	33.89	117.92
800	0.65	29.37	26.44	35.28	36.14	108.16
900	0.22	18.70	11.89	16.70	26.23	68.10
1000	0.36	14.70	8.47	11.24	54.13	59.84
1100	0.59	12.50	8.07	7.11	66.64	43.21

The contents of the tested metals in the soils of the southern slope of Jaworzyna Krynicka were compared with the global geochemical background (average content of the element in the Earth's crust according to Turkian and Wedepohl [24]) and with the local geochemical background of Polish soils proposed by Czarnowska [25]. Generally, the contents of all tested heavy metals in the soils of Jaworzyna Krynicka are higher than the global and local geochemical background values. This may indicate anthropogenic pollution in the studied area. Traffic and industrial pollution resulted in increased content of heavy metals in mountainous and naturally valuable areas. The negative impact of human activity on environmental pollution was also observed by Paprotny, et al. [26], Małecka-Adamowicz, et al. [27], Kwiecińska-Poppe, et al. [28], Fabijańczyk, et al. [29] and Stankiewicz, et al. [30].

Conclusion

The average metal concentrations for the altitudes of 700 and 800 m MSL were the highest for copper, zinc, nickel, cadmium, and chromium. An increase in the content of these metals from an altitude of 500 to 800 m MSL was observed, and then a decrease in concentration from 900 to 1100 m MSL. Lead content increased with the increase in altitude.

The analysis confirms that metal pollution can occur even in areas with no metal emission. Especially mountain areas that constitute an orographic barrier to winds are exposed to the deposition of pollutants carried by winds from industrialized areas.

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