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The Influence of Dust Emission From the "Głogów" Copper Foundry on Heavy Metal Concentrations in Agrocenoses

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Abstract

Complex five-year studies were led on the pollution of agrocenoses affected by a copper foundry. Lead, copper, zinc and cadmium levels were determined in the soil, water and plants by means of AAS. Samples were collected from two villages situated in the zone of western winds blowing most frequently in that region. The content of metals, particularly Cu and Pb, depends largely on the distance from the source of emission. Studies revealed that plant pollution was caused mainly by current dust emission and not only by concentration of metals in the soil.

Keywords: heavy metals, copper foundry, pollution, soil, water, plants

Introduction

Increased concentrations of heavy metals in soil, water and plants poses a serious threat to human and animal health [1]. One of the frequent reasons for the accumulation of metals in the ecosystem's food chains is industrial emission, coming mainly from non-ferrous metallurgy [2-7].

This paper is a synthesis of several-year studies carried out in agricultural areas threatened ecologically by the "Glogow" Copper Foundry [7, 8]. Dust emissions from the foundry, apart from other toxic substances, contains considerable amounts of heavy metals, particularly copper and lead - the main pollutants of the natural environment [5, 6, 9-12]. These pollutants (above all lead) belong to a group of elements whose influence on the biosphere is very harmful [1, 11, 12]. The most degraded areas around the foundry were excluded from cultivation, forming a so-called protection zone planted with poplar trees. The foundry's harmful influence, however, extends over the currently existing agrocenoses, so it is extremely important to monitor both emission and imission in those areas.

The aim of these studies is to work out such a model of farming which would exclude the heavy metal-prone species and, simultaneously, support agro-practices restricting circulation of these elements in the ecosystem.

Experimental Procedures

The studies were carried out during vegetative seasons 1993-1997 and covered three elements of the biosphere: soil, water and plants. The samples were collected from three sites fertilized in different ways and located at different distances from the source of emission: a garden, fertilized intensely with manure (2.0 km NE of the foundry, a village called Bogomice); a fallow field in the same village; and an experimental plot under moderate fertilization (5.5 km NEE, a village called Grodziec Maly) - see the map in Baluk et al. [3].

The contents of Cu, Pb, Zn and Cd were determined by means of atomic absorption spectrophotometry (AAS) in the previously mineralized extracts of soil and plant samples and in the condensed samples of water [13]. In the soil samples, apart from the total content of metals, the size of absorbable fraction extracted with 1M hydrochloric acid (HCl) was also determined. Soil pH was determined in 1M sodium chloride (KCl). The level of metals in soil and water is presented as an average of the samples collected in June and September. The content of metals in crops was determined when they were ripe. The tables give average values as well as the minimum and maximum values.

Results and Discussion

The level of water, soil and cultivated plant pollution observed over the years 1993-1997 are presented in Tables 1-5.

The content of metals in the soil, particularly of copper and lead, decreased proportionally to the distance from the source of emission (Tab. 1) The same tendency was observed for the total concentration of metals and their absorbable fraction extracted with 1M HCl. The results confirm the data obtained by other researches who carried out analyses in the same areas in previous years [2, 6, 14].

The method of soil fertilization seems to have had a considerable effect on the level of heavy metals in the soil. The soil samples from the garden fertilized with the solid and liquid manure from a local farm were much more polluted with metals than those from the remaining sites (Tab. 1). Analyses of metal content in excrement and body fluids of the cattle grazing within the area affected by the foundry show that natural fertilizers may be an additional source of environmental pollution. Natural fertilizers have already been identified as a possible source of metals in the soil by Tiller [1].

Table 1. Concentrations of metals in soil and its acidity.

Metals concentration mg kg^{-1}		Site, direction and distance from source of emission		
		Garden	Fallow field	Experimental plot
		Bogomice, NE, 2.0 km		Grodziec Mały, NEE, 5.5 km
Copper	Total	496 (482-510)	233 (230-236)	101 (88-108)
	Extracted 1 M HCl	438 (432-445)	212 (207-221)	91 (77-107)
Lead	Total	244 (233-255)	93 (90-97)	59 (55-63)
	Extracted 1 M HCl	203 (203-204)	85 (83-86)	49 (43-55)
Zinc	Total	183 (159-207)	50 (47-52)	97 (68-130)
	Extracted 1 M HCl	124 (120-128)	30 (28-32)	55 (20-103)
Cadmium	Total	1.45 (1.33-1.58)	0.75 (0.68-0.82)	1.12 (0.75-1.31)
	Extracted 1 M HCl	0.66 (0.63-0.69)	0.27 (0.19-0.36)	0.31 (0.19-0.35)
pH	1 M KCl	6.5 (6.3-6.8)	6.0 (5.6-6.5)	6.2 (5.8-6.6)

average values, minimum and maximum values in brackets

Table 2. Concentrations of metals in water.

Metals concentration µg dm^{-3}	Sample, site, direction and distance from source of emission		
	Ground water	Surface water	Surface water
	Bogomice, NE, 2.0 km		Grodziec Mały, NEE, 5.5 km
Copper	30 (16-62)	16 (7-31)	10 (5-16)
Lead	51 (37-72)	38 (17-62)	31 (26-40)
Zinc	326 (91-804)	42 (16-92)	78 (24-120)
Cadmium	6 (2-13)	4 (1-7)	4 (1-8)

Bioavailability of metals to plants depends to a large extent on the chemical form of metals and their solubility in water [16]. Surface waters, independent of their distance from the foundry, contained slight amounts of metals as compared with their concentration in the soils (Tabs. 1, 2). Ground water was more polluted than surface waters, which may result from the amount and chemical form of metals introduced with organic fertilizers (Tab. 2). The level of lead and cadmium in the samples of ground water collected from three different sources (a hydrophore, an open well and a hand pump well) exceeded the standards established for drinking water [17]. The analyzed metals show different solubility in 1M HCl, which is a measure of the sorptive strength of the soil complex (Tab. 1). Lead and copper exhibit good washability in acid environments (over 80%), but cadmium's washability is much weaker (below 50%). These data confirm the results of studies from the years 1974-1978 [2]. A considerable solubility of lead and copper which occur in the surface layers of the soil facilitates their uptake by plants [11,12]. Being included in the food chains, they become a threat to the environment [1].

Pollution of cultivated plants, particularly their aboveground parts, was correlated with the distance from the source of emission and with the direction and strength of the winds blowing most frequently in that region (Tabs. 3-5). Pods, leaves and coat corncobs were more contaminated than seeds and corn kernels. This proves that current dust emission and not the concentration of metals in the soil was the main reason for plant pollution. This fact is convergent with the results obtained by Rosada et al. [18, 19, 20] and Spiak et al. [6]. In the case of root crops grown in the garden fertilized with solid and liquid manure (Bogomice) a clear correlation was observed between these plants' pollution and the concentration of metals in the soil (Tab. 4). This was particularly visible in red beets where the level of metals in the leaves and entire roots (including epidermis) exceeded the admissible standards [21]. Many other authors indicate a high cummulation of metals in entire red beets as compared with other vegetables [22, 23]. On the other hand, Rosada et al. [8] report that the distribution of metals in root crops is uneven. While considerable amounts of metals are cummulated in the epidermis, their level in the parenchyma does not exceed admissible standards [21].

Table 3. Concentrations of metals in corn.

Metals concentration mg kg^{-1} dry weight	Part of plant	Site, direction and distance from source of emission	
		Garden	Experimental plot
		Bogomice, NE, 2.0 km	Grodziec Mały, NEE, 5.5 km
Copper	corn	2.5 (1.4-3.4)	2.0 (1.1-2.6)
	leaves coat corncobs	22.4 (6.3-34.1)	21.5 (11.8-43.0)
Lead	corn	0.6 (0.5-1.0)	0.5 (0.3-1.2)
	leaves coat corncobs	8.1 (2.8-11.2)	8.8 (2.0-33.5)
Zinc	corn	32.4 (31.5-33.2)	24.6 (21.9-28.7)
	leaves coat corncobs	40.3 (27.5-53.2)	39.6 (30.5-52.8)
Cadmium	corn	0.07 (0.03-0.12)	0.05 (0.01-0.14)
	leaves coat corncobs	0.12 (0.08-0.17)	0.20 (0.03-0.60)

Table 4. Concentrations of metals in carrot and red beet.

Metals concentration mg kg^{-1} dry weight	Part of plant	Site, direction from source of emission and plant			
		Garden		Experimental plot	
		Bogomice, NE, 2.0 km		Grodziec Mały, NEE, 5.5 km	
		carrot	red beet	carrot	red beet
Copper	Roots	9.9 (4.6-14.7)	16.6 (11.0-28.5)	6.6 (4.4-11.2)	10.9 (5.7-21.7)
	Leaves	67.9 (26.7-98.6)	68.6 (38.1-101.5)	25.4 (15.8-32.2)	33.9 (12.4-48.3)
Lead	Roots	2.4 (0.8-4.0)	2.5 (1.0-3.9)	1.3 (0.6-1.9)	2.3 (1.0-4.5)
	Leaves	22.3 (3.7-64.7)	23.0 (3.8-43.3)	8.7 (4.0-13.6)	7.9 (1.3-16.4)
Zinc	Roots	30.1 (18.5-49.9)	55.9 (31.5-82.2)	23.0 (14.5-28.0)	34.1 (23.7-48.6)
	Leaves	57.7 (39.8-84.7)	79.3 (52.3-99.0)	35.5 (19.8-56.7)	55.7 (39.3-88.4)
Cadmium	Roots	0.16 (0.04-0.37)	0.16 (0.07-0.45)	0.15 (0.12-0.23)	0.38 (0.08-0.88)
	Leaves	0.31 (0.10-0.48)	0.44 (0.22-0.74)	0.23 (0.08-0.35)	0.51 (0.25-1.01)

Table 5. Concentrations of metals in bean and horse bean.

Metals concentration mg kg^{-1} dry weight	Part of plant	Site, plant direction and distance from source of emission	
		Garden, Bean	Experimental plot, Horse bean
		Bogomice, NE, 2.0 km	Grodziec Mały, NEE, 5.5 km
Copper	Seeds	6.9 (4.8-9.4)	13.6 (9.7-16.9)
	Pods	18.2 (9.3-35.0)	17.4 (5.89-38.0)
Lead	Seeds	0.5 (0.3-0.6)	0.5 (0.3-0.8)
	Pods	6.4 (2.0-11.2)	3.2 (0.5-6.7)
Zinc	Seeds	37.3 (36.1-38.7)	48.7 (25.8-71.0)
	Pods	24.6 (22.5-28.6)	34.9 (34.8-35.0)
Cadmium	Seeds	0.08 (0.02-0.13)	0.04 (0.02-0.07)
	Pods	0.12 (0.03-0.30)	0.08 (0.05-0.15)

The content of Pb and Cu in the soil and in vegetables from the garden at Bogomice corresponded to a considerable concentration of lead in the blood of people consuming those vegetables [24]. Moreover, a high level of metals was detected in the blood, milk, liver, kidneys, bones, hair and excrements of the cattle grazing in that region [3, 4, 15, 25, 26].

The results of the studies confirm the thesis that in the area affected by emission from industrial plants, such as copper foundries, heavy metals-prone plants should be excluded from cultivation. Moreover, appropriate agrochemical practices must be applied. First of all, organic fertilization (liquid and solid manure from the local sources) should be limited, while the application of liming should be encouraged.

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